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THE GEOLOGIC HISTORY OF CHINA AND ITS INFLUENCE UPON THE CHINESE PEOPLE

By Professor ELIOT BLACKWELDER
UNIVERSITY OF WISCONSIN

THE Chinese empire includes an area larger than the United States with the addition of Alaska and our insular possessions. A large part of this vast area, however, is made up of dependencies which are but loosely joined to China proper, and are not essential to its integrity. She has lost and regained these dependencies from time to time in the past, and the same process may continue. The accompanying map will serve to show the relation of these component parts of the empire to each other and to surrounding countries.

Divested of its outlying possessions, China consists of eighteen

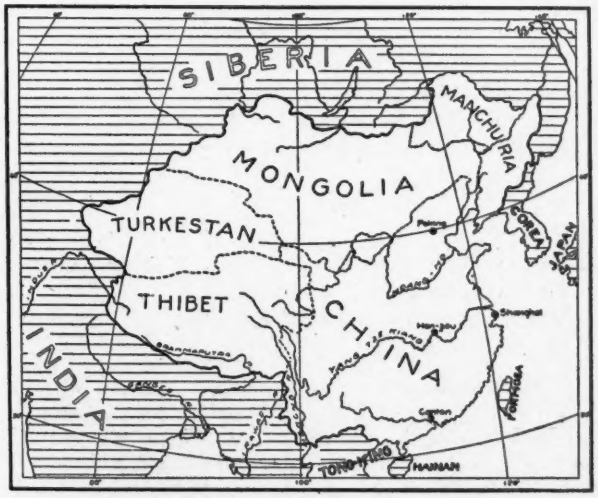


Fig. 1. Sketch Map of China, showing its outlying dependencies and its relations to other countries.

provinces, which may be compared in a general way to our states. The provinces are, however, generally larger than the states and on the whole much more populous. There is still greater dissimilarity in government because, whereas our states are representative democracies, the Chinese provinces were, at least until within a year or two, satrapies ruled absolutely by imperial governors or viceroys.

Not a few people in America picture China as a vast fertile plain, perhaps like the upper Mississippi valley, densely populated and intensively cultivated. In fact, however, it is so generally mountainous, that less than one tenth of its surface is even moderately flat. On the west, especially, it is ribbed with cordilleras from which its two great rivers, the Yang-tze-Kiang and the Huang-ho flow eastward to the Pacific.

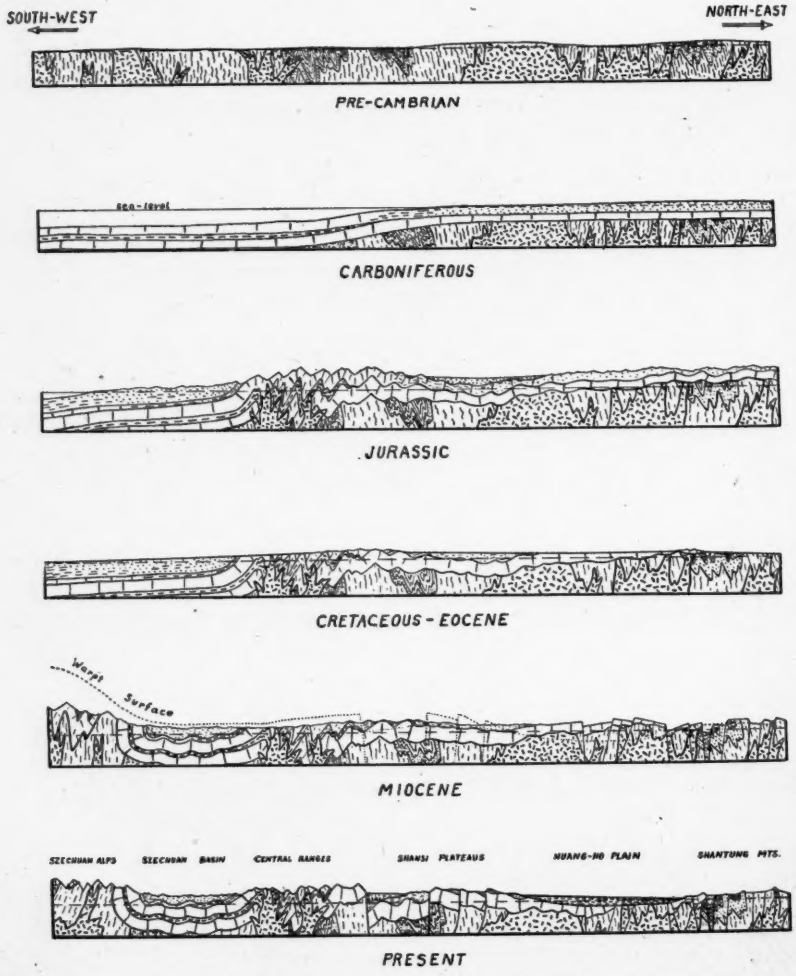


FIG. 2. DIAGRAMS TO ILLUSTRATE GEOLOGICAL CONDITIONS IN CHINA AT DIFFERENT PERIODS IN ITS HISTORY. The features are necessarily much generalized and in part hypothetical.

FIG. 3. RELIEF MAP, showing in the enclosed part how the Yellow River, by its frequent changes of course, has spread over all parts of its vast alluvial fan.

In addition to this diversity of surface there is also much variety of climate. In the northwest the conditions are dry and severe like those of Montana and central Wyoming; while in the southeast they are humid and sub-tropical, approaching those of the Philippine Islands. Such are the extremes.

It is a fact well known to geologists that continents, and therefore countries, have not always existed in their present state, but that they have been built as a result of successive events and changes of conditions. If we were to dig beneath the surface in any part of China, we should find first one stratum and then another, and we should see also that these strata have been bent, cracked and otherwise disturbed. Some of these structures are old and some young. It would be somewhat like excavating in an ancient city, where one house or temple has been built upon the ruins of its predecessor, and each affords a crude record of its time. The geologic structure of such a country as China has been de-

FIG. 4. LOW ISOLATED MOUNTAIN GROUP IN NORTHEASTERN CHINA.

FIG. 5. TWO FARMERS RAISING WATER FROM THE GRAND CANAL INTO THE HEAD OF AN IRRIGATING DITCH BY MEANS OF A WICKER BASKET SLUNG BETWEEN THEM.

FIG. 6. A WIDE RIVER PLAIN AMONG THE MOUNTAINS OF SHAN-TUNG. The bridge of stone slabs across the sand-laden river is part of the principal wheel-barrow road of the valley.

FIG. 7. A TYPICAL CITY WALL, WITH GATE TOWER.

termined largely by the rocks of which it consists, partly by the climate to which it has been subject, but chiefly by the geologic events which have occurred during its history. Of course the beginnings of that history are unknown, just as the human history of China shades into darkness when we attempt to trace it back into the remote ages. But the present features of the land are chiefly due to the later events in its life, and these have been partly worked out by the geologists who have explored its surface.

We may take as a convenient starting point for our interpretation a time far back in geologic chronology[1] when China was a land surface which had been exposed to erosion so long that nearly all the hills and mountains that may have existed there before had been worn away, leaving a relatively flat plain with groups of low hills here and there. The rocks beneath this plain were of various kinds, most of them highly folded. Eventually this surface was submerged beneath a comparatively shallow inland sea, and although the uneasy movements of the earth's body caused the sea bottom to emerge occasionally, it remained below the water nearly all through the geologic periods which constitute the Paleozoic era. By the end of that time we may picture China as a shallow sea bottom rising very gradually to a marshy coastal plain on the east. During the long intervening ages the accumulation of sediments upon the sea bottom had formed successive layers of limestone,

[1] Just before the Cambrian period.

[2] Jurassic period.

shale, and sandstone, which eventually reached a thickness of 5,000–10,000 feet.

This condition did not hold without end, for eventually[2] strong compressive forces, engendered in the underlying body of the earth, squeezed the superficial rocks into folds, and thus bulged the surface high above sea level in the region so affected. By the prompt attack of streams, winds, glaciers, and the other agencies which are incessantly sculpturing the surface of the earth, these elevated districts were, even while rising, carved into rugged mountains and deep valleys, so that the original folds were greatly disfigured even before the compressive forces ceased to operate.

It is a fact generally recognized among geologists, that in terms of geologic time such episodes of compression and folding are short-lived. They are soon followed by much longer periods during which the internal forces of the earth are quiescent, but in which the erosive agencies have free play. If any land remains indefinitely above sea level, and is not disturbed by movements from below, the mountains and hills will eventually be worn away and there will be left only a broad almost featureless plain. It is believed that China, in consequence of such a period of quiescence,[3] was reduced to a lowland from which almost all of the preexisting mountains had been removed. In this condition it probably remained for more than one geologic period, and the western part may even have been submerged beneath the sea which at that time

FIG. 8. HEAVILY LOADED FREIGHT WHEEL-BARROWS WITH MULES FOR MOTIVE POWER.

FIG. 9. A TYPICAL PASSENGER CART.

FIG. 10. FREIGHT WHEEL-BARROWS RIGGED TO TAKE ADVANTAGE OF A FAVORABLE WIND.

FIG. 11. A MEDIUM-SIZED HOUSE-BOAT USED ON THE YANG-TZE-KIANG AND ITS TRIBUTARIES.

[3] Cretaceous and Eocene periods.

FIG. 12. SOIL RESERVOIRS ON A HILLSIDE IN THE LOESS COUNTRY.

covered northern India and part of Thibet. In that sea were deposited the thick beds of limestone which are now found in some of the western mountain ridges.

Again in the Miocene period, the forces of distortion within the earth accumulated to such strength that they were able to repeat the mashing and folding, but this time the area affected lay farther to the west and south. At the same time, or perhaps earlier, the eastern part of China was cracked in various directions; and the intervening blocks, settling somewhat unevenly upon their bases, left a group of escarpments and depressions comparable to those now to be found in western Nevada and southern Oregon. As before, the work of erosion and the leveling of the surface was at once accelerated, so that even before the deformation had spent itself the blocks were deeply scarred. It is uncertain how far this period of erosion succeeded in reducing China to base-level. The consummation may have been prevented by gentle warpings of the surface, rising very slowly here and sinking there. When compared with the great breadth of the areas affected, these changes of level seem very slight, but they are nevertheless sufficient to cause great changes in the aspect of the country.

It is one of the basal principles of physiography that streams tend to produce in their channels an almost uniform slope from their headwaters to the sea. If any part of the channel is so flat that the stream is too sluggish to carry sediment, it is built up until it reaches the re-

quired gradient; and on the other hand, if any part has too steep a declivity, it is gradually worn down to the proper slope. In consequence of this law, the parts of China which were slightly bulged above their original level were re-attacked by the branching systems of rivers with renewed vigor. By carving out the softer rocks, these have made deep valleys with intervening mountain ranges. Some of the larger rivers, such as the Yang-tze-kiang, maintained their courses in spite of the slow uplifts directly athwart their courses. A result is the magnificent series of gorges along the central Yang-tze where the great river has sawed its way through a slowly rising mass of hard complexly folded rocks.

On the other hand, the broad areas which were depressed not only below the general level of stream action, but below sea-level, were rapidly filled with sand, loam and clay washed down out of the adjacent mountains by the streams. The process of filling the depressions is the exact complement of the process of etching out the highlands. No doubt the rivers have been able in large measure to keep pace with the sinking movement of the ground, so that great rivers like the Huang-ho may have maintained perfectly graded courses across the region of depression from the mountains to the sea. While thus engaged in building up its channel, the river in time of flood frequently breaks through its low banks, shifts its channel, and then begins to fill up a

FIG. 13. MOUNTAIN SLOPES IN NORTHWESTERN CHINA, terraced to prevent the erosion of the loess.

new and hitherto lower part of its surroundings. By the long continuance of this process of repeated shiftings and fillings, the great eastern plain of China and many smaller plains have been produced. It is here, where the population is densest and the rivers least confined, that the devastation by floods and their attendant famines is greatest.

By this succession of events the surface of China is believed to have reached its modern condition. We may now consider it piecemeal and see how the existing geologic conditions, which are the result of this long series of past changes, influence the habits, occupations and even mental traits of the people. Because space is limited and also because I have not seen all the physiographic divisions of China, it will not be possible for me, even briefly, to describe each of them. A few are therefore selected to show the range of variety of the whole.

FIG. 14. CAVE HOUSES IN THE LOESS, FACED WITH STONE.

FIG. 15. MEN AND DONKEYS CARRYING COAL FROM THE MINES IN SHANSI.

FIG. 16. A PACK TRAIN OF DONKEYS, ON THE IMPERIAL HIGHWAY OVER THE LOESS PLATEAU.

FIG. 17. A ROADSIDE VILLAGE AND SMALL FIELDS AT THE BOTTOM OF THE MOUNTAIN VALLEY.

The mountains of northeastern China, typified by the province of Shantung, are unlike those of the rest of the country in several respects. Although the individual peaks are often sharp and rocky, they are generally separated by wide, flat-bottomed valleys. The process of erosion has here gone so far that the rivers have already carried away most of the land, leaving only isolated groups of low mountains. The broad valleys accommodate a relatively large number of people, who congregate in the villages dotting the intermontane plains. In contrast with most mountainous regions, travel between the different valleys is comparatively easy here, because many of the passes are but little higher than the plains themselves and constitute scarcely any obstacle to prog-

ress. Roads are plentiful, and so the cart and the wheel-barrow are the principal vehicles for through traffic.

This is one of the few parts of China where boats can be but little used. The streams are shallow and full of sand bars, and on account of the pronounced wet and dry seasons many of them are intermittent. For these reasons the majority of them are not navigable. The deeply eroded land of Shan-tung has, however, suffered a relatively recent

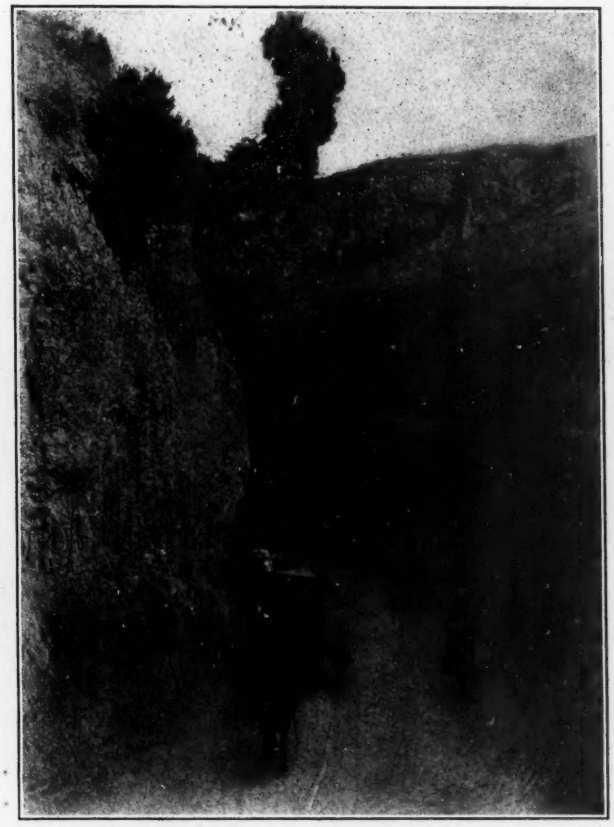


FIG. 18. A ROADWAY SUNK DEEP INTO THE LOESS BY CENTURIES OF TRAVEL.

movement—apparently a sinking of the land—which has allowed the ocean to penetrate the mouths of many of the coastal valleys. This marginal drowning has produced some excellent harbors—such as that of Chee-fu, the great silk port, and Tsing-tau, the German stronghold.

On the west, and encircling the Shantung hills, lies the great plain of the Huang-ho or Yellow River, which will serve as the type of many much smaller plains in various parts of China. As explained before, this vast gently sloping plain has been built by the Yellow River and some of its tributaries in an effort to preserve a uniform gradient across

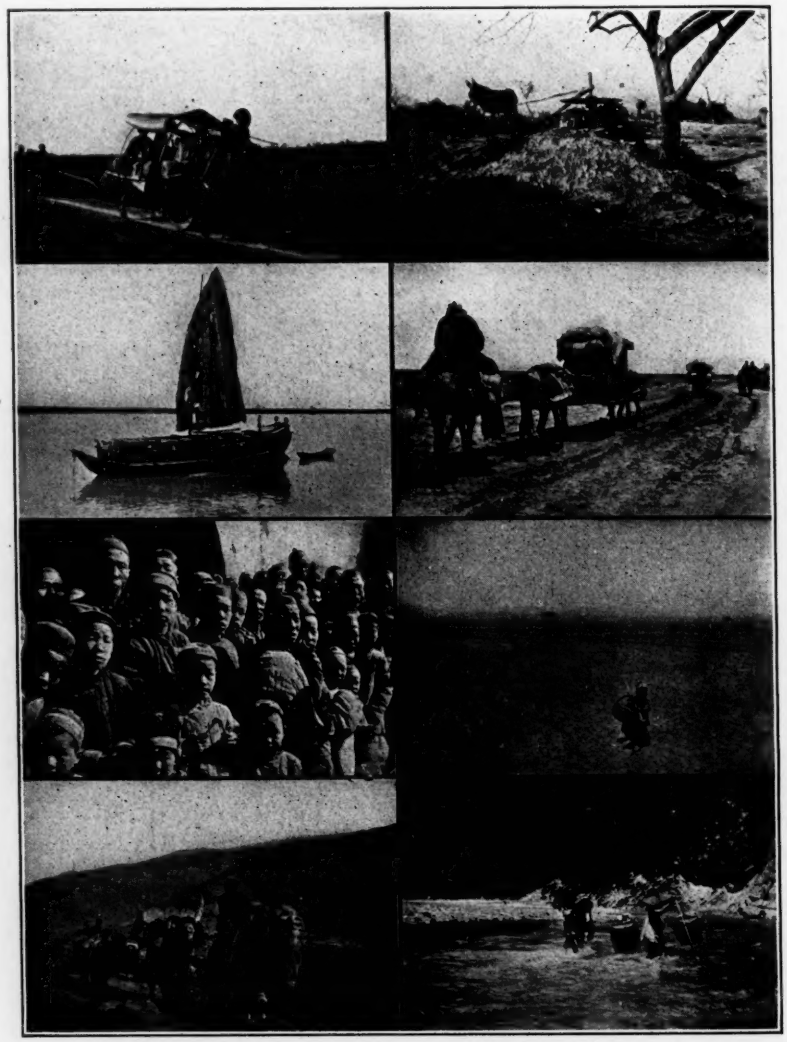


FIG. 19. A TWO-MAN WHEEL-BARROW CARRYING A MERCHANT AND HIS STOCK OF GOODS.

FIG. 20. A RIVER JUNK.

FIG. 21. A FRIENDLY CROWD IN AN INLAND TOWN.

FIG. 22. MONGOLIAN CAMELS IN NORTHWESTERN CHINA.

FIG. 23. IRRIGATING WITH WATER PUMPED FROM A WELL.

FIG. 24. A SEDAN CHAIR SWUNG BETWEEN TWO MULES.

FIG. 25. GETTING HIS INITIATION INTO FARMING, WITH GRUB-HOOK AND BASKET.

FIG. 26. COOLIES FORDING A MOUNTAIN RIVER.

the sunken portion of eastern China. Like the lower Mississippi and all other rivers which are building up rather than cutting down their beds, the Huang-ho is subject to frequent floods and occasional shiftings of its channel. Its course between the mountains and the sea has thus been changed more than fifteen times in the last 3,000 years.

In these incessant shiftings, the river has strewn all over an enormous area, 500 miles from north to south by 300 miles from east to west, layer after layer of fine yellow loam or silt; the very name "Yellow River," which is a translation of the Chinese "Hwang-ho," suggests the close resemblance to our own mud-laden Missouri. Almost every square foot of this vast alluvial fan is of course underlain by a deep and fertile soil and is intensively cultivated by the industrious Chinese inhabitants. One sees no large fields of grain, such as those on our Dakota prairies, but instead, thousands of small truck gardens belonging to the inhabitants of the hundreds of little mud-walled villages with which the plain is dotted. The ever-present town walls have doubtless been built because the inhabitants have no natural refuges, as their mountain cousins have, and their very accessibility has made them in the past the frequent prey of Mongol and Tartar invaders, or of rebels and rioters from within their own country.

Since the water supply of the plain is not lavish, but little rice is grown there. The dry-land grains, and such vegetables as cabbages and potatoes, are the staple crops. The small gardens are sparingly irrigated, however, in times of drought, by water taken from the canals or wells with the help of various types of crude pumps, operated by men or by donkeys.

In this densely populated alluvial plain there is practically no pasturage and no woodland. From the very nature of the plain it could not yield coal, which is always associated with the solid rocks. To bring fuel, as we do, from distant parts of the country is impossibly expensive for the Chinese, without an adequate railroad system, and that is still a thing of the future. When the harvest has been gathered in the autumn, the village children are therefore sent out to gather up every scrap of straw or stubble that can be used either for fodder or for fuel. The fields thus left perfectly bare in the dry winter season afford an unlimited supply of fine dust to every wind that blows. This is doubtless the explanation of the disagreeable winter dust-storms with which every foreigner who has lived in northern China is only too familiar.

Although carts and wheel-barrows are much used on the Huang-ho plain, their traffic is chiefly local. That may be due in part to the fact that the numerous wide and shifty rivers are difficult to bridge, while ferrying is relatively expensive. Another, and perhaps more important, reason is that the rivers, and particularly their old abandoned courses, afford natural waterways which are available nearly everywhere. By taking advantage of these, or by deepening them, and in some places by actually digging canals through the soft material of the plain, the Chinese have put together the wonderful system of interlaced canals for which they have been renowned since Europeans first visited them.

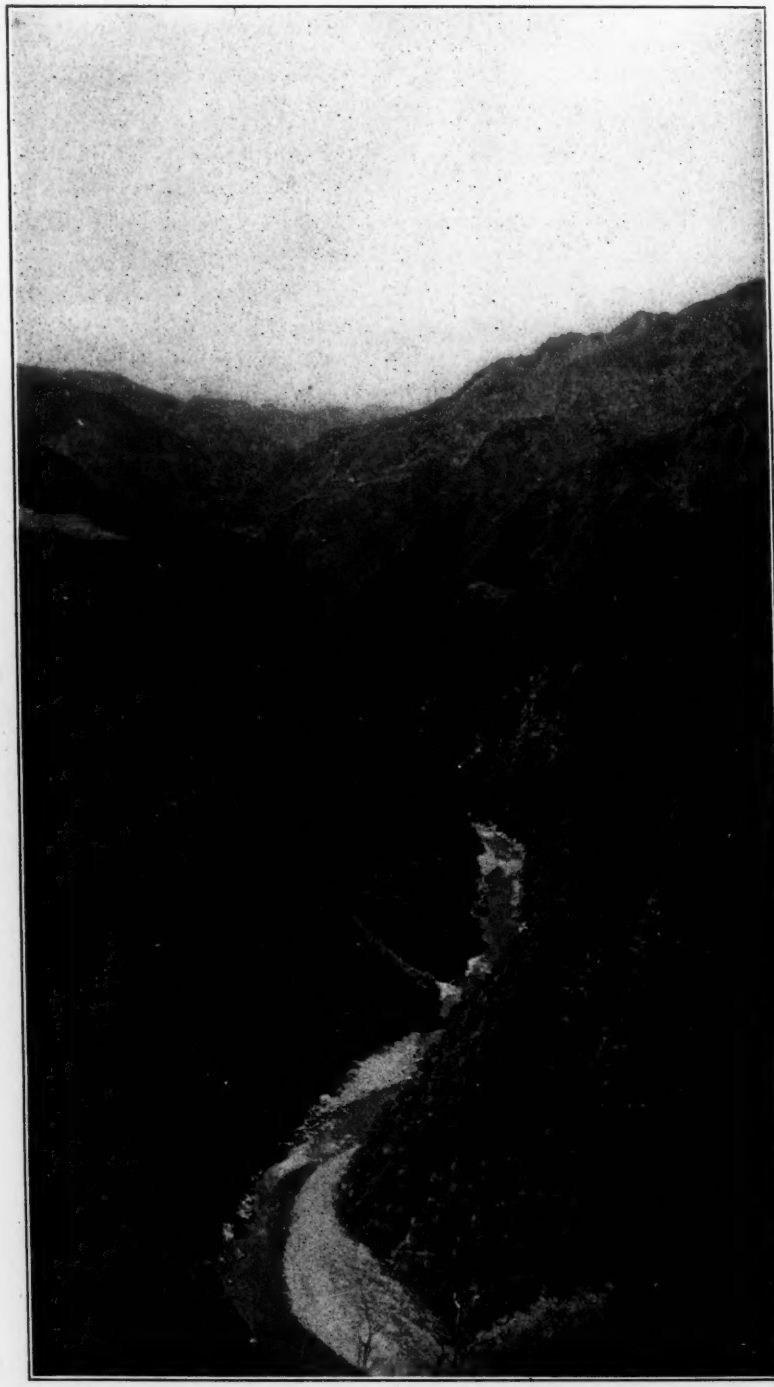


FIG. 27. A VALLEY IN THE TSIN-LING MOUNTAINS OF CENTRAL CHINA. Small cultivated fields may be seen on benches high above the river.

The thousands of junks which ply these waterways maintain a volume of inland commerce, which is inferior only to that of the great railroad countries, such as the United States. The relative freedom of communication in this great plain of the Yellow River has helped to bring about a greater homogeneity in the people than in any other equally large part of China. Here we find a single dialect in use over the entire region, whereas in some parts of southern China the natives of even adjacent valleys speak languages almost unintelligible to each other. The other common effects of isolation, such as the lack of acquaintance with the customs of outside peoples, the hatred of foreigners, the peculiar local usages, and many other things, are less prominent here than in other parts of the empire. Excepting the coastal cities, there is no safer part of China for foreigners to travel through.

West and northwest of the Yellow River plain lie the more rugged plateaus and mountains of northwest China, with their sub-arid climate presaging the approach to the deserts of Mongolia. Over much of this region the ancient limestones and sandstones are still horizontal or are gently folded, with occasional dislocations along faults. On account of the comparatively recent uplift and differential warping which this part of China has suffered, the streams have been greatly accelerated in their work, so that they have hollowed out canyons in the raised portions and have filled in the depressed basins with sand and silt. This is the region celebrated among geologists on account of the loess, or yellow earth, which lines the basins and mantles the hillsides everywhere. It is believed that this is very largely a deposit of wind-blown dust, although it has been worked over considerably by the streams from time to time. No doubt Baron von Richthofen, the distinguished German explorer, was near the truth when he concluded more than forty years ago, that the "yellow earth" was the dust of the central Asian deserts carried into China by the northwest winds. The presence of the loess determines, in large measure, the mode of living adopted by the inhabitants. Because of its fertility and moisture-conserving properties, it is well adapted to dry farming, and there is little water for irrigation. The Chinese are not content with using the level bottom lands, but successfully cultivate the hillsides wherever a deposit of the loess remains. In order to prevent the soil from washing off from these steep slopes, they build a series of stone walls, thus forming soil reservoirs or terraces. In this way nearly all of the soil is utilized.

In such a country rivers are not numerous and those which exist have many rapids and shoals. Boats are therefore but little used in northwest China. For both passenger and freight traffic, pack animals or rude vehicles are the chief reliance. For passengers there are also the palanquin or sedan-chair and the mule-litter. Where the country is not too rough, the two-wheeled cart is the usual conveyance for mer-

FIG. 28. COOLIES CARRYING FREIGHT ALONG A MOUNTAIN TRAIL WHICH HAS BEEN PARTLY WASHED OUT BY A TURBULENT STREAM.

chandise. Over the mountain passes, however, and in many of the smaller valleys, roads are so narrow that carts can not be used, and so here pack animals, particularly horses and mules, are substituted. The traveler in this part of China is often reminded of his proximity to Mongolia by the frequent sight of camels. They are nevertheless not indigenous beasts of burden and the inhabitants themselves do not use them.

In consequence of the swampy state which prevailed in this part of China far back in the Carboniferous period, thick deposits of coal were formed. These are now exposed in the deep valley slopes between beds of limestone and sandstone, and the circumstance has made Shansi province the principal coal-producing district of China. The coal is mined by very primitive methods and as there is still no adequate system of railroads in this or any other part of the empire, the product can be transported only in carts or on pack animals. Either of these modes of carriage is so expensive that it becomes unprofitable to transport the coal more than 60 to 100 miles from the mine, and so the denizens of a great part of northern China, where fuel is scarce and the winters are severe, are no more able to obtain it than as if the United States contained the only coal fields in the world. The advantages that will accrue from the building of railroads in northern China are many, but one of the greatest will be the wide distribution of this essential fuel.

In going south by west from the plateau country, one enters a region of warmer climate and more generous rainfall, which, for want of a more distinctive name, I have called the Central Ranges. This is the part of China which was particularly affected by the rock-folding movements of the Jurassic period, and which in a much more recent time has been reelevated and therefore newly attacked by the streams and other erosive agencies. Broadly regarded, it is a complex of sharp mountain ridges and spurs with narrow intervening valleys. The ridges are not so high, however, but that they are clad with vegetation, and the scenery is therefore not alpine. The surface is nevertheless very rugged and its internal relief averages at least 3,000 feet. The roughest parts of our Carolinas resemble it in a measure. In such a region obviously, there is no room for a dense population. Wherever there is a little widening of the bottom of the valley, there is a farm or occasionally a small village; and even the scattered benches high up the mountain sides are reached by steep trails and diligently cultivated. But even when all of these are combined, the total area of land under settlement is relatively small.

In this region there are no railroads whatever, and although wagon roads could be built in some places, they would be expensive, and the Chinese have not yet attempted to make them. All travel and com-

FIG. 29. RIVER SKIFFS IN ONE OF THE LIMESTONE GORGES OF THE CENTRAL RANGES.

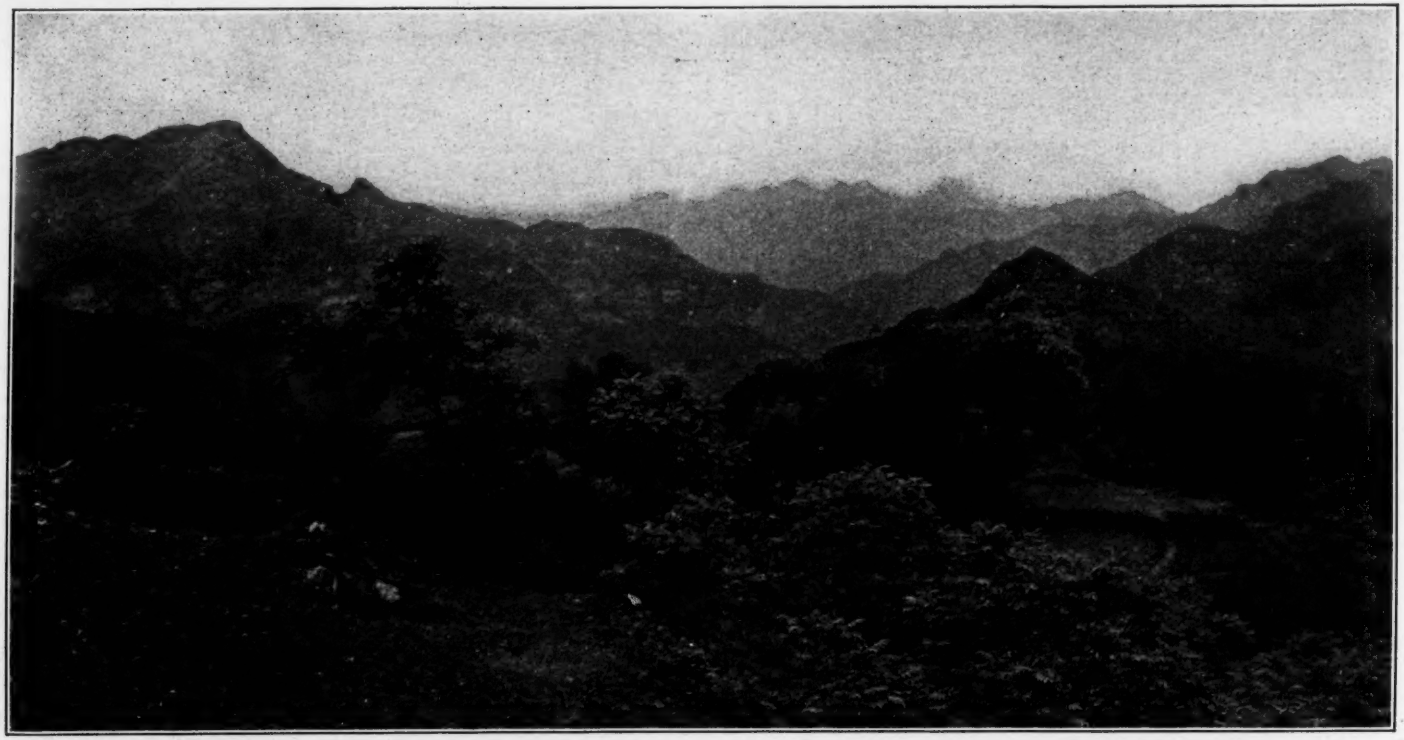


FIG. 30. AN OPEN VIEW IN THE MOUNTAINS BORDERING THE BASIN OF SZE-CHWAN.

merce, therefore, depend on the agency of pack animals or coolies, and the roads they follow are mere trails winding around the steep mountain sides or threading the bottoms of narrow valleys, where swift streams must be forded at frequent intervals. Under such circumstances it is evident that there can be but little effective traffic. Only comparatively light and expensive articles can be transported long distances. Around the edges of the mountain mass where the populous cities of the adjoining plains can be reached with one or two days' travel, there has been for centuries an important trade in lumber. The mountains have now been so largely deforested, however, that it is necessary to go farther and farther back into the heads of the valleys to find large trees. Hence, only the more expensive kinds of lumber such as coffin boards—which are absolutely indispensable, even to the poorer classes, —can profitably be brought out. These are often carried for 20 or 30 miles on the backs of coolies—a costly mode of transportation. The smaller trees and brush the mountaineers convert into charcoal, which they carry on their own backs down to the towns along the foothills.

Lack of transportation facilities is doubtless the chief reason why the opium poppy has in the past been widely cultivated in this part of China, although the practise has lately been prohibited by the government. The advantage in poppy culture was that it could be carried on in small scattered fields and the product was so valuable for unit of weight that it would pay for long-distance transportation across the mountains. The inhabitants of the region themselves were not, however, generally addicted to the use of the drug.

The rainfall of the central mountain region is sufficient to supply the many springs and tributary brooks of which the people have made use in irrigation. The mildness of the climate here permits the growing of rice, and by terracing the hillsides they are able to make a succession of narrow curved basins in which the aquatic crop may be grown. For the cultivation of rice it is necessary that the fields be completely submerged during part of the season, and so there must be a plentiful supply of water.

On the larger rivers such as the Han and the Yang-tze, and their chief tributaries, boats are successfully used. In fact, the Chinese river boatmen are so skilful in the handling of their high-prowed skiffs, that they navigate canyons full of rapids which most of us would consider too dangerous to attempt. The descent of one of these rivers is an easy although exciting experience. The return trip, however, is slow and laborious, for the boats must be dragged upstream by coolies harnessed to a long bamboo rope, which has the advantage of being very light as well as strong. In the many places where the river banks are so precipitous that it is impossible to walk along them, it becomes neces-

FIG. 31. A VALLEY IN THE CENTRAL RANGES. In the foreground are a series of terraced rice fields now filled with water.

sary for the boatmen to pole around the cliff or to zigzag from one side of the river to the other to take advantage of every foothold.

Through the central part of this mountain uplift, the great Yang-tze River, which in its lower course readily accommodates large ocean-going vessels, has carved a succession of superb gorges. In many places the gray limestone walls rise from 3,000 to 4,000 feet above the river, and the stream is compressed into less than a tenth of its usual width. Difficult and dangerous as are these canyons, beset with rapids and whirlpools, they afford the only ready means of communication between eastern China and the fertile basin of Sze-chuan, which lies west of the Central Ranges.

Without the highway of the Yang-tze, this great province, four times as large as Illinois and with more people than all of our states east of the Mississippi River, would be unable to export its many rich products or to enjoy the commerce of outside provinces and nations. It has been effectually barred off from India and Burma by the succession of high ranges and deep canyons which appear to be due primarily to the great epoch of folding in the Miocene period. Sze-chuan is a broad basin which has never been depressed low enough to force the streams to level its bottom with alluvial deposits, as in the Yellow River plain to the east; nor does it seem to have been elevated into a high plateau which would have been carved by many streams into a

rugged mountain country. The soft red sandstone beds which underlie it have therefore been sculptured into a network of valleys with intervening red hills or buttes. With a climate as mild and moist as that of Alabama, and a diversified topography, there is opportunity for many industries, and for the cultivation of a great variety of crops. Sze-chuan leads all the provinces in the exportation of silk. Here grow the lacquer and oil nut trees and a wide range of field and garden fruits, grains and vegetables. Ample water for irrigation and especially for rice-culture is supplied by the many perennial streams which descend from the encircling mountains. These uplifted and now mountainous tracts have also served as a barrier to invaders from all directions, so that this has been less subject to wars than almost any other part of China, and hence has been more stable in development. Its inhabitants are among the most substantial and progressive components of the Chinese nation.

We now come to the last of the geologic divisions which were laid out for consideration. From the Sze-chuan basin southwest to the

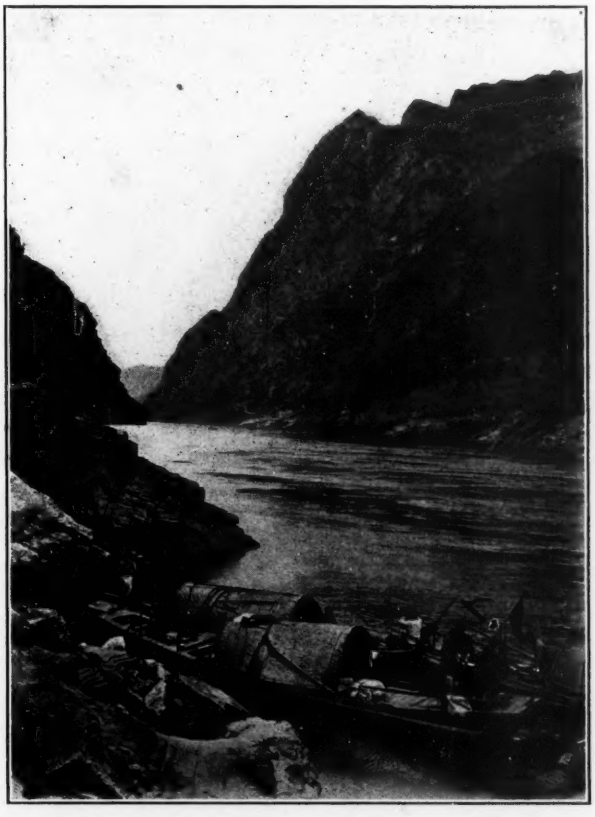


FIG. 32. ONE OF THE GREAT LIMESTONE GORGES THROUGH WHICH THE YANG-TZE-KIANG PIERCES THE CENTRAL RANGES.

confines of India there extends a series of high mountain ranges separated by deep and narrow valleys, all trending in a south or southeasterly direction. Although not so high above sea-level as the mountains north and south of Thibet, these ranges are an even more effective barrier to travel because they are so continuous and the relief is so great. Not only is there no waterway, but there are no wagon roads, and the building of a railroad would be a stupendous and expensive engineering task. Such a road would necessarily involve the making of a succession of long bridges and tunnels. Here, as in the Central Ranges, settlements are limited to the rare open spots in the bottoms of valleys, and so the population is sparse indeed. The total commerce is very small in volume, because goods must be carried almost entirely on the backs of coolies. The rugged characteristics of the region are evidently the direct result of the recency of the compressive movement which produced the tremendous mountain folds, and perhaps are still more due to the renewed uplifts which have permitted the streams to continue the carving of their deep gorges. This part of China is geologically very young, and to quote the words of the distinguished old geologist of California, Joseph LeConte, "the wildness of youth (here) has not yet been tempered by the mellowness of age."

FRENCH GEODESY

By the late HENRI POINCARÉ
Translated by GEORGE BRUCE HALSTED

EVERY one understands our interest in knowing the form and dimensions of our earth; but some persons will perhaps be surprised at the exactitude sought after. Is this a useless luxury? What good are the efforts so expended by the geodesist?

Should this question be put to a congressman, I suppose he would say: "I am led to believe that geodesy is one of the most useful of the sciences; because it is one of those costing us most dear." I shall try to give you an answer a little more precise.

The great works of art, those of peace as well as those of war, are not to be undertaken without long studies which save much groping, miscalculation and useless expense. These studies can only be based upon a good map. But a map will be only a valueless phantasy if constructed without basing it upon a solid framework. As well make stand a human body minus the skeleton.

Now, this framework is given us by geodesic measurements; so, without geodesy, no good map; without a good map, no great public works.

These reasons will doubtless suffice to justify much expense; but these are arguments for practical men. It is not upon these that it is proper to insist here; there are others higher and, everything considered, more important.

So we shall put the question otherwise: can geodesy aid us the better to know nature? Does it make us understand its unity and harmony? In reality an isolated fact is of slight value, and the conquests of science are precious only if they prepare for new conquests.

If therefore a little hump were discovered on the terrestrial ellipsoid, this discovery would be by itself of no great interest. On the other hand, it would become precious if, in seeking the cause of this hump, we hoped to penetrate new secrets.

Well, when, in the eighteenth century, Maupertuis and La Condamine braved such opposite climates, it was not solely to learn the shape of our planet, it was a question of the whole world-system.

If the earth was flattened, Newton triumphed and with him the doctrine of gravitation and the whole modern celestial mechanics.

And to-day, a century and a half after the victory of the Newtonians, think you geodesy has nothing more to teach us?

We know not what is within our globe. The shafts of mines and borings have let us know a layer of 1 or 2 kilometers thickness, that is to say, the millionth part of the total mass; but what is beneath?

Of all the extraordinary journeys dreamed by Jules Verne, perhaps that to the center of the earth took us to regions least explored.

But these deep-lying rocks we can not reach exercise from afar their attraction which operates upon the pendulum and deforms the terrestrial spheroid. Geodesy can therefore weigh them from afar, so to speak, and tell us of their distribution. Thus will it make us really see those mysterious regions which Jules Verne only showed us in imagination.

This is not an empty illusion. M. Faye, comparing all the measurements, has reached a result well calculated to surprise us. Under the oceans, in the depths, are rocks of very great density; under the continents, on the contrary, are empty spaces.

New observations will modify perhaps the details of these conclusions.

In any case, our venerated dean has shown us where to search and what the geodesist may teach the geologist, desirous of knowing the interior constitution of the earth, and even the thinker wishing to speculate upon the past and the origin of this planet.

And now, why have I entitled this chapter *French Geodesy?* It is because, in each country, this science has taken, more than all others perhaps, a national character. It is easy to see why.

There must be rivalry. The scientific rivalries are always courteous, or at least almost always; in any case, they are necessary, because they are always fruitful.

Well, in those enterprises which require such long efforts and so many collaborators the individual is effaced, in spite of himself, of course; no one has the right to say: this is my work. Therefore it is not between men, but between nations, that rivalries go on.

So we are led to seek what has been the part of France. Her part I believe we are right to be proud of.

At the beginning of the eighteenth century long discussions arose between the Newtonians who believed the earth flattened, as the theory of gravitation requires, and Cassini, who, deceived by inexact measurements, believed our globe elongated. Only direct observation could settle the question. It was our Academy of Sciences that undertook this task, gigantic for the epoch.

While Maupertuis and Clairaut measured a degree of meridian under the polar circle, Bouguer and La Condamine went toward the Andes Mountains, in regions then under Spain which to-day are the Republic of Ecuador.

Our envoys were exposed to great hardships. Traveling was not as easy as at present.

Truly, the country where Maupertuis operated was not a desert, and he even enjoyed, it is said, among the Laplanders those sweet satisfac-

tions of the heart that real arctic voyagers never know. It was almost the region where, in our days, comfortable steamers carry, each summer, hosts of tourists and young English people. But in those days Cook's agency did not exist and Maupertuis really believed he had made a polar expedition.

Perhaps he was not altogether wrong. The Russians and the Swedes carry out to-day analogous measurements at Spitzbergen, in a country where there is real ice-cap. But they have quite other resources, and the difference of time makes up for that of latitude.

The name of Maupertuis has reached us much scratched by the claws of Doctor Akakia; the scientist had the misfortune to displease Voltaire, who was then the king of mind. He was first praised beyond measure; but the flatteries of kings are as much to be dreaded as their displeasure, because the days after are terrible. Voltaire himself knew something of this.

Voltaire called Maupertuis, my amiable master in thinking, marquis of the polar circle, dear flattener out of the world and Cassini, and even, flattery supreme, Sir Isaac Maupertuis; he wrote him: "Only the king of Prussia do I put on a level with you; he only lacks being a geometer." But soon the scene changes, he no longer speaks of deifying him, as in days of yore the Argonauts, or of calling down from Olympus the council of the gods to contemplate his works, but of chaining him up in a madhouse. He speaks no longer of his sublime mind, but of his despotic pride, plated with very little science and much absurdity.

I care not to relate these comico-heroic combats; but permit me some reflections on two of Voltaire's verses. In his "Discourse on Moderation" (no question of moderation in praise and criticism), the poet has written:

> You have confirmed in regions drear
> What Newton discerned without going abroad.

These two verses (which replace the hyperbolic praises of the first period) are very unjust, and doubtless Voltaire was too enlightened not to know it.

Then, only those discoveries were esteemed which could be made without leaving one's house.

To-day, it would rather be theory that one would make light of.

This is to misunderstand the aim of science.

Is nature governed by caprice, or does harmony rule there? That is the question. It is when it discloses to us this harmony that science is beautiful and so worthy to be cultivated. But whence can come to us this revelation, if not from the accord of a theory with experiment? To seek whether this accord exists or if it fails, this therefore is our aim. Consequently these two terms, which we must compare, are as indispensable the one as the other. To neglect one for the other would be non-

sense. Isolated, theory would be empty, experiment would be blind; each would be useless and without interest.

Maupertuis therefore deserves his share of glory. Truly, it will not equal that of Newton, who had received the spark divine; nor even that of his collaborator Clairaut. Yet it is not to be despised, because his work was necessary, and if France, outstripped by England in the seventeenth century, has so well taken her revenge in the century following, it is not alone to the genius of Clairauts, d'Alemberts, Laplaces that she owes it; it is also to the long patience of the Maupertuis and the La Condamines.

We reach what may be called the second heroic period of geodesy. France is torn within. All Europe is armed against her; it would seem that these gigantic combats might absorb all her forces. Far from it; she still has them for the service of science. The men of that time recoiled before no enterprise, they were men of faith.

Delambre and Méchain were commissioned to measure an arc going from Dunkirk to Barcelona. This time there was no going to Lapland or to Peru; the hostile squadrons had closed to us the ways thither. But, though the expeditions are less distant, the epoch is so troubled that the obstacles, the perils even, are just as great.

In France, Delambre had to fight against the ill will of suspicious municipalities. One knows that the steeples, which are visible from so far, and can be aimed at with precision, often serve as signal points to geodesists. But in the region Delambre traversed there were no longer any steeples. A certain proconsul had passed there, and boasted of knocking down all the steeples rising proudly above the humble abode of the sans-culottes. Pyramids then were built of planks and covered with white cloth to make them more visible. That was quite another thing: with white cloth! What was this rash person who, upon our heights so recently set free, dared to raise the hateful standard of the counter-revolution? It was necessary to border the white cloth with blue and red bands.

Méchain operated in Spain; the difficulties were other; but they were not less. The Spanish peasants were hostile. There steeples were not lacking: but to install oneself in them with mysterious and perhaps diabolic instruments, was it not sacrilege? The revolutionists were allies of Spain, but allies smelling a little of the stake.

"Without cease," writes Méchain, "they threaten to butcher us." Fortunately, thanks to the exhortations of the priests, to the pastoral letters of the bishops, these ferocious Spaniards contented themselves with threatening.

Some years after, Méchain made a second expedition into Spain: he proposed to prolong the meridian from Barcelona to the Balearics. This was the first time it had been attempted to make the triangulations

overpass a large arm of the sea by observing signals installed upon some high mountain of a far-away isle. The enterprise was well conceived and well prepared; it failed however.

The French scientist encountered all sorts of difficulties of which he complains bitterly in his correspondence. "Hell," he writes, perhaps with some exaggeration, "hell and all the scourges it vomits upon the earth, tempests, war, the plague and black intrigues, are therefore unchained against me!"

The fact is that he encountered among his collaborators more of proud obstinacy than of good will and that a thousand accidents retarded his work. The plague was nothing, the fear of the plague was much more redoubtable; all these isles were on their guard against the neighboring isles and feared lest they should receive the scourge from them. Méchain obtained permission to disembark only after long weeks upon the condition of covering all his papers with vinegar; this was the antisepsis of that time.

Disgusted and sick, he had just asked to be recalled, when he died.

Arago and Biot it was who had the honor of taking up the unfinished work and carrying it on to completion.

Thanks to the support of the Spanish government, to the protection of several bishops and, above all, to that of a famous brigand chief, the operations went rapidly forward. They were successfully completed, and Biot had returned to France when the storm burst.

It was the moment when all Spain took up arms to defend her independence against France. Why did this stranger climb the mountains to make signals? It was evidently to call the French army. Arago was able to escape the populace only by becoming a prisoner. In his prison his only distraction was reading in the Spanish papers the account of his own execution. The papers of that time sometimes gave out news prematurely. He had at least the consolation of learning that he died with courage and like a Christian.

Even the prison was no longer safe; he had to escape and reach Algiers. There, he embarked for Marseilles on an Algerian vessel. This ship was captured by a Spanish corsair, and behold Arago carried back to Spain and dragged from dungeon to dungeon, in the midst of vermin and in the most shocking wretchedness.

If it had only been a question of his subjects and his guests, the dey would have said nothing. But there were on board two lions, a present from the African sovereign to Napoleon. The dey threatened war.

The vessel and the prisoners were released. The port should have been properly reached, since they had on board an astronomer; but the astronomer was seasick, and the Algerian seamen, who wished to make Marseilles, came out at Bougie. Thence Arago went to Algiers, traversing Kabylia on foot in the midst of a thousand perils. He was long

detained in Africa and threatened with the convict prison. Finally he was able to get back to France; his observations, which he had preserved and safe-guarded under his shirt, and, what is still more remarkable, his instruments, had traversed unhurt these terrible adventures.

Up to this point, not only did France hold the foremost place, but she occupied the stage almost alone.

In the years which follow she has not been inactive and our staff-office map is a model. However, the new methods of observation and calculation have come to us above all from Germany and England. It is only in the last forty years that France has regained her rank. She owes it to a scientific officer, General Perrier, who has successfully executed an enterprise truly audacious, the junction of Spain and Africa. Stations were installed on four peaks upon the two sides of the Mediterranean. For long months they awaited a calm and limpid atmosphere. At last was seen the little thread of light which had traversed 300 kilometers over the sea. The undertaking had succeeded.

To-day have been conceived projects still more bold. From a mountain near Nice will be sent signals to Corsica, not now for geodesic determinations, but to measure the velocity of light. The distance is only 200 kilometers; but the ray of light is to make the journey there and return, after reflection by a mirror installed in Corsica. And it should not wander on the way, for it must return exactly to the point of departure.

Ever since, the activity of French geodesy has never slackened. We have no more such astonishing adventures to tell; but the scientific work accomplished is immense. The territory of France beyond the sea, like that of the mother country, is covered by triangles measured with precision.

We have become more and more exacting and what our fathers admired does not satisfy us to-day. But in proportion as we seek more exactitude, the difficulties greatly increase; we are surrounded by snares and must be on our guard against a thousand unsuspected causes of error. It is needful, therefore, to create instruments more and more faultless.

Here again France has not let herself be distanced. Our appliances for the measurement of bases and angles leave nothing to desire, and I may also mention the pendulum of Colonel Defforges, which enables us to determine gravity with a precision hitherto unknown.

The future of French geodesy is at present in the hands of the Geographic Service of the army, successively directed by General Bassot and General Berthaut. We can not sufficiently congratulate ourselves upon it. For success in geodesy, scientific aptitudes are not enough; it is necessary to be capable of standing long fatigues in all sorts of climates; the chief must be able to win obedience from his collaborators

and to make obedient his native auxiliaries. These are military qualities. Besides, one knows that, in our army, science has always marched shoulder to shoulder with courage.

I add that a military organization assures the indispensable unity of action. It would be more difficult to reconcile the rival pretensions of scientists jealous of their independence, solicitous of what they call their fame, and who yet must work in concert, though separated by great distances. Among the geodesists of former times there were often discussions, of which some aroused long echoes. The Academy long resounded with the quarrel of Bouguer and La Condamine. I do not mean to say that soldiers are exempt from passion, but discipline imposes silence upon a too sensitive self-esteem.

Several foreign governments have called upon our officers to organize their geodesic service: this is proof that the scientific influence of France abroad has not declined.

Our hydrographic engineers contribute also to the common achievement a glorious contingent. The survey of our coasts, of our colonies, the study of the tides offer them a vast domain of research. Finally I may mention the general leveling of France which is carried out by the ingenious and precise methods of M. Lallemand.

With such men we are sure of the future. Moreover, work for them will not be lacking; our colonial empire opens for them immense expanses illy explored. That is not all: the International Geodetic Association has recognized the necessity of a new measurement of the arc of Quito, determined in days of yore by La Condamine. It is France that has been charged with this operation; she had every right to it, since our ancestors had made, so to speak, the scientific conquest of the Cordilleras. Besides, these rights have not been contested and our government has undertaken to exercise them.

Captains Maurain and Lacombe completed a first reconnaissance, and the rapidity with which they accomplished their mission, crossing the roughest regions and climbing the most precipitous summits, is worthy of all praise. It won the admiration of General Alfaro, President of the Republic of Ecuador, who called them "los hombres de hierro," the men of iron.

The final commission then set out under the command of Lieutenant-Colonel (then Major) Bourgeois. The results obtained have justified the hopes entertained. But our officers have encountered unforeseen difficulties due to the climate. More than once, one of them has been forced to remain several months at an altitude of 4,000 meters, in the clouds and the snow, without seeing anything of the signals he had to aim at and which refused to unmask themselves. But thanks to their perseverance and courage, there resulted from this only a delay and an increase of expense, without the exactitude of the measurements suffering therefrom.

THE RÔLE OF MEMBRANES IN CELL-PROCESSES

By Professor RALPH S. LILLIE
UNIVERSITY OF PENNSYLVANIA

THE importance of membranes in vital processes has long been recognized. From the earliest times anatomists have been impressed with the frequency with which thin sheets of solid material occur as elements of structure in organisms. Even elementary methods of analysis show that the materials composing the most various organs often tend to dispose themselves in thin, continuous layers. Thus the entire body is enclosed in an extremely resistant and impermeable layer, the skin. Each of the internal organs has its own characteristic enclosing membrane; the peritoneum lines the body-cavity and invests the intestine and its associated glands, the heart is enclosed in the pericardium, the lungs in the pleura, the central nervous system in the pia mater; the muscles are closely surrounded by thin connective tissue sheaths, or perimysia; the walls of the blood-vessels and of the intestine and other hollow viscera consist of several distinct concentric layers. Various products of animals, like the eggs of birds and reptiles, often show this tendency. Plants also deposit a great part of their structural materials in layers; the wood forms concentric circles; leaves and fruits have thin and often waterproof membranous coverings; the orange is partitioned by a system of membranes and each smaller portion of pulp has a membrane of its own. The instances, in fact, are innumerable. Evidently the tendency to deposit material in thin continuous sheaths is highly characteristic of organisms.

This much was clear at a time when anatomists were limited to direct and unaided vision. When the microscope came into use the existence of a similar tendency soon became evident in the minutest tissue-elements. The living substance exhibited itself everywhere as minutely subdivided by innumerable thin partitions, or membranes, giving it a characteristic honeycomb-like or cellular structure. These partitions isolate the enclosed portions of living substance and render them at least mechanically separable. Hence the conception that each of these minute membrane-enclosed masses of gelatinous or viscid "protoplasmic" material is an independently living entity, or elementary physiological unit, gained ground, and, as all know, has been universally adopted in biology. The name "cell," originally applied to the minute spaces themselves, has been transferred to the protoplasmic mass within, by whose activity the enclosing membrane is itself formed.

Thus it was early recognized that cells tend to separate materials

from their surfaces and deposit them in the form of definite coherent layers or membranes. Similar membranes may also be formed in the cell-interior. Of these, the best known is the nuclear membrane. Hence, in considering the general organization of the cell, cytoplasm and nucleus are usually described as bounded by definite structurally distinct layers, plasma-membrane and nuclear membrane. Vacuole-membranes, sphere-membranes and plastid-membranes may also exist in certain cells. To all of these structures it has been customary to ascribe a more or less mechanical or simply protective or isolating function. On the other hand, many cells show no optically distinguishable membranes, either at their surfaces or in their interior; certain ameboid cells and the blood-corpuscles of vertebrates are apparently without membranes and are often described as "naked masses of protoplasm." Yet in such cases the nakedness is only apparent, for it can readily be shown that these cells have membranes which are highly definite in character, but whose existence can be demonstrated only by certain forms of physiological experimentation.

The membranes whose physiological rôle forms the subject of this article are not to be identified with those more or less conspicuous layers separated at the surfaces of many animal and plant cells. The cellulose membranes of plant cells and the various cuticular structures of animal cells are dead structures, whose function is typically passive and mechanical. They are to be sharply distinguished from the membranes about to be considered, whose rôle is a characteristically active one, and, as I believe, fundamentally important in the life of all cells. These membranes are present in all living cells without exception, whether a visible external layer is present or not. Thus red blood corpuscles, though typically naked cells, show by their behavior in salt-solutions of varying concentration that they are bounded by a difficultly permeable surface-layer which is different in its physical properties from the internal protoplasm—having in fact the essential properties of a semi-permeable membrane. Plant cells, like those of *Spirogyra,* also behave in such solutions as if the surface-layer of the protoplasm were semi-permeable; the visible cellulose membrane plays no part whatever in the osmotic process (plasmolysis) observed under such conditions, while the invisible surface-film of the protoplasm is all-important. Hence in the case of plant cells the conceptions of cell-membrane—*i. e.,* the hardened secretion of cellulose—and of plasma-membrane—or semi-permeable surface layer of the living protoplasm—have to be kept sharply distinct. It is the plasma-membrane, the most external layer of the living protoplasm, with which I shall be chiefly concerned in the present article, and I propose to discuss briefly various questions which arise in reference to this structure: what is its physical and chemical nature? what are the conditions of its formation? and how does it influence the characteristic activities of the cell?

Before dealing with the case of the living plasma-membrane, it will be necessary briefly to describe some of the methods by which artificial membranes, similar in many of their osmotic and other physical properties to plasma-membranes, may be prepared, and to consider some of the properties of these membranes. The tendency of the living cell (or living system) to surround itself with a membrane will then be seen to be in no sense a distinctively vital peculiarity, but one which it exhibits in common with a great many non-living systems. There is little doubt that the formation of membranes at the surface of small masses of living protoplasm is a particular instance of the general class of phenomena known collectively as "surface-processes"—processes, that is, occuring as manifestations of the special form of energy, surface-energy, which resides at the surface of separation between materials which do not freely intermix. Consider any material system consisting of various kinds of matter in various states of aggregation, *i. e.*, what the physical chemists call a heterogeneous system, or a *polyphasic* system. Such a system may be analyzed into a certain number of components, each of which is physically and chemically homogeneous. Each such component is a *phase*. Oil-drops in a permanent emulsion form one phase, the water a second phase, the soap films at the surface of each droplet a third. Living protoplasm is a good instance of such a polyphasic system. It is—at least in certain forms, *e. g.*, the protoplasm of egg-cells—an emulsion-like or foam-like mixture consisting of various fluid droplets or alveoli (which are supposedly droplets of oil or other fluid containing dissolved substances), separated by another fluid which is typically an aqueous colloidal solution of proteins and lipoids with various additional substances—salts, sugars, amino-acids—in solution. Each droplet or alveolus is a phase; so also is each colloidal particle, or each surface-film, or the interstitial suspension-medium or solvent. At the surface of contact between any two phases a certain tension exists, acting tangentially to the surface; this is the "surface-tension" which (if positive in value) tends to minimize the area of the surface. Each surface, or phase-boundary, is thus the seat of a particular form of energy, surface-energy, of which the intensity-factor is the surface-tension (T), the capacity-factor the total area of the surface (A). The total surface-energy (E) resident at any surface thus equals TA. The tension varies according to the nature of both of the contiguous phases: for water in contact with air it is *ca.* 75 dynes per linear centimeter, *i. e.*, the pull of a ribbon-shaped portion of water-surface one centimeter wide is about one twelfth of a gram; for water in contact with oil it is *ca.* 23 dynes per centimeter; for oil in contact with air it is *ca.* 33 dynes. Now the distribution of the substances present in any such system is influenced in a remarkable manner by these surface-energies. Every one is familiar with the fact that oil spreads over the surface of pure water. This is a case in point: why does the oil not simply float

in droplets on the surface instead of spreading out in an extremely thin continuous layer? A consideration of the conditions of surface-tension at once explains this (Fig. 1). An oil-drop placed on the surface of water is subjected to the pull of three tensions, viz.: those at its own two surfaces (t_1 and t_2), where it touches air and water, respectively, and which tend to round it off, and that of the pure water at its margin (t_3), which tends to spread it. But the tensions t_1 and t_2 are together less than the tension t_3; the oil is thus rapidly drawn out over the surface by the superior pull of the water-air tension at its margin. Hence the water-air surface, that with high tension, disappears and is replaced by a surface with lower tension. The total surface-energy has been diminished, part having been transformed into mechanical energy and heat. If, instead of the case of a floating oil-drop, we take that of some soluble substance which is produced locally within the water near the surface—*e. g.*, a soap or a protein, a solution of which has a lower tension than pure water—we find essentially the same phenomenon; the substance is spread out over the surface, and this effect will continue so long as the addition of further quantities of the substance to the surface-layer continues to lower the surface-tension. The end-effect will be to concentrate the substance at the phase-boundary. This phenomenon is the expression of a general law, the law of Willard Gibbs and J. J. Thomson, which describes the part played by surface-energies in the distribution of soluble substances in a polyphasic system. In the present case, the process of surface-concentration will go on until some equilibrium is reached, *e. g.*, where the loss of substance from the surface by diffusion balances its collection there under the influence of the surface-energy. But in many cases, as with proteins, soaps and certain lipoids, the substance separates at the surface as a continuous solid film before this stage is reached. The formation of solid surface-films is hence highly characteristic of the solutions of such substances. Casein films form on warm milk, soap films form about droplets of rancid oil in the presence of alkali, and protein films about drops of chloroform or oil suspended in protein solutions. Thin solid membranes formed in this manner at phase-boundaries are called "haptogen membranes." In all of these instances we have to do with a surface-condensation, known under certain conditions as "adsorption," of substances which lower the surface-tension at the phase-boundary. Among the colloidal constituents of protoplasm the proteins and the lipoids belong to this class of substances. Hence it is not surprising that isolated portions of living protoplasm should delimit themselves by membranes. The vari-

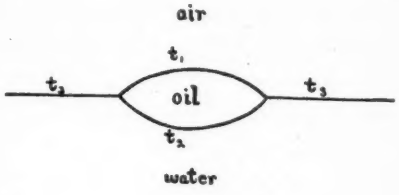


FIG. 1.

ous cell-membranes are to be regarded as essentially surface-films, or haptogen membranes. Not only do such thin films form about the reconstituting nuclei of dividing cells, but they are also deposited about various cell-inclusions, and even about division-spheres, chromatophores and other cell structures under certain conditions. It is well known that portions of protoplasm cut off from living cells—such as egg-cells, protozoa, root-hairs, etc.—exhibit the same osmotic properties as the intact cells, showing that new semi-permeable membranes are quickly formed at the cut-surfaces.

The surface of contact of the living substance with its medium thus becomes the seat of deposition of certain protoplasmic constituents or products which form membranes, often of a high degree of impermeability. This impermeability is a property of fundamental physiological importance. Speculation on the evolutionary origin of living cells usually leads to little result, but we may at least infer that the early protoplasmic systems which survived and became the ancestors of living organisms must have consisted in part of colloids like proteins and lipoids which had the property of forming surface-films sufficiently impermeable to limit or prevent free diffusive interchange with the surroundings. Only systems thus isolated to a sufficient degree from the surroundings could preserve the requisite complexity and constancy of composition, and hence be enabled to develop the properties of so-called living beings—properties which are so widely different from those shown by other natural systems. The surface-films, or plasma-membranes, of living cells at the present time are in fact typically characterized by a remarkably high impermeability to simple crystalloid substances like sugars, neutral salts and amino-acids, all of which are important constituents of protoplasm. Zangger expresses the situation concisely when he says that living cells can contain as permanent constituents only such substances as are not free to diffuse into the surrounding medium. The existence of this diffusion-preventing or insulating surface-film, the plasma-membrane, is thus a necessary condition of the stability of the living system and hence of the continuance of the life-processes. The living condition is in fact incompatible with marked and permanent increase in surface-permeability. During life the semi-permeable condition is retained; on death there is always a marked increase in the permeability of the plasma-membrane; the cell then undergoes a ready and rapid dissolution or cytolysis, and the constituents serve as food to bacteria. It is probable that the various intracellular membranes—nuclear membranes, vacuole-membranes, sphere-membranes, chromatophore-membranes—subserve a similar insulating or differentiating function. Hofmeister has indeed conceived of the protoplasm of living cells as subdivided in this manner into a many-chambered system, which accordingly permits of a high degree of chemical differentiation. A variety of independent processes

might coexist side by side in such a system, as appears, for example, to be the case in liver-cells; in this way a "chemical organization," distinct from and yet dependent upon a structural organization, becomes possible.

Haptogen membranes formed thus by deposition of proteins at phase-boundaries may show considerable density and impermeability. The protein in such surface-films may undergo an alteration resembling coagulation, assuming a relatively resistant and insoluble form, Thus Ramsden was able to coagulate protein solutions by prolonged shaking, and Robertson obtained thin films of coagulated casein, gelatine and protamine at the surface of chloroform droplets. Solid films of albumose, saponin, and other substances are formed at the free surfaces of their solutions—the readiness with which such solutions are thrown into foams depends in fact on this condition. The condensed and insoluble protein films formed on chloroform droplets are strikingly similar in many respects to those visible at the surfaces of cells like sea-urchin eggs, and which apparently correspond to the outer layer of the true plasma-membranes.

To come now to more directly biological considerations: what is the nature, chemical and physical, of the surface-film of living cells? There are few direct chemical analyses bearing on this question. Liebermann found the vitelline membrane of the hen's egg to consist largely of a keratin-like albuminoid. There is good reason to believe that modified proteins belonging to this class enter very generally into the composition of the surface-films of cells. The tendency to deposit horny or albuminoid material at the cell-surfaces is in fact remarkably widespread in animals. Cuticular and epidermal structures, to which chemical resistance and impermeability are physiologically essential, consist typically of proteins belonging to this class; such proteins have recently been called "scleroproteins" on account of their frequent presence in skeletal or cuticular structures. They are also abundant in the intercellular materials of bone, cartilage and connective tissue. The surface-films of many cells apparently have this composition. Thus in echinoderm eggs the characteristic fertilization-membranes, which Professor Jacques Loeb has shown to arise by separation of a surface-film, consist apparently of modified protein. They are at least non-lipoid in character and are remarkably resistant to reagents, resembling in these respects the protein films formed at the surface of chloroform droplets. The fertilization-membrane, after separation from the cell, proves however to be much more permeable than the true plasma-membrane, or semi-permeable external layer of the unaltered egg, so that it probably corresponds to only a portion—probably the outer layer—of this membrane. The presence of protein in the plasma-membrane of sea-urchin eggs is also indicated by the fact that the cytolytic action of

acids may be lessened or counteracted by neutral salts like sodium or calcium chloride. Such antagonistic actions between acids and salts, while not shown by colloids in general, are peculiarly characteristic of certain proteins. Thus the rate of swelling of gelatine (a typical scleroprotein) in water is greatly increased by the addition of a little acid; this effect is prevented by the addition of neutral salts, and the basis of this form of anti-cytolytic action may possibly lie here—*i. e.*, the disruptive action of the acid on the proteins of the membrane is checked or prevented by the salt.[1] Yet the plasma-membrane undoubtedly contains other constituents, and among these the substances belonging to the group of lipoids appear to be fundamentally important. These substances, fat-like in their solubilities and colloidal in their physico-chemical character, are always present in cells. Much light has been thrown on their physiological significance by the investigations of Overton and his successors, which have shown that ready permeability to lipoid-solvents is highly characteristic of both animal and plant cells. Alcohols, esters, ethers, hydrocarbons and similar compounds, all of which are soluble in lipoids, enter living cells rapidly, in contrast to neutral salts, sugars, amino-acids—the chief crystalloidal constituents of protoplasm—which diffuse into resting cells (with unmodified plasma-membrane) either imperceptibly or with extreme slowness. Overton's results thus indicate that lipoids enter into the composition of the plasma-membrane. This is to be expected. The structure probably consists of a mixture of all those protoplasmic constituents which have marked effect in lowering the surface-tension of the cell-boundary. Lipoids are conspicuous among this group of substances. That they form part of the plasma-membrane is also indicated by the readiness with which the permeability and other properties of this structure may be altered by lipoid-modifying substances. Lipoid-solvents as a class, when present in certain concentrations, have a specific action in increasing, often irreversibly, the permeability of the plasma-membrane. In lower concentrations many appear to *decrease* this permeability. Their influence on irritability, which is probably a function of the condition of this membrane, also indicates their importance as membrane-constituents. Narcotic action is highly characteristic of lipoid-solvents, and there is good evidence that this action depends on an alteration of the plasma-membrane. I shall refer to this possibility later, in connection with the problem of the relation of membranes to stimulation. All of these facts taken together indicate very clearly that the colloids composing the semi-permeable surface-film of living cells consist of

[1] This consideration, however, is not demonstrative. The precipitation of lecithin by acid can be prevented by salts in concentrations which in themselves do not precipitate, as Handowsky and Wagner have recently shown. Lecithin, which seems always to be present in cells, probably forms an important part of the plasma membrane, in which case changes in its physical condition would influence the properties of the latter.

both lipoids and proteins, which are probably intermixed or combined in some characteristic manner and vary in their relative proportions in different cells, according to the specific constitution of the latter.

What are the chief peculiarities in the physical properties of these membranes, on which their physiological importance depends? Two properties appear especially significant. One of these is the semi-permeability which the membranes preserve during life, *i. e.*, the ability to transmit water freely while holding back dissolved substances. The other is their ability to undergo reversible changes in their permeability to such substances, either in the direction of increase or decrease. These changes of permeability may in some cells be very rapid; and there is evidence that this is especially the case with irritable tissues, and that the power of rapid response to stimuli is directly dependent on this peculiarity. How essential the semi-permeability of the plasma-membranes is to living organisms may be realized with especial clearness in the case of plants. In many of these organisms the rate of growth, the normal form and habit, and the characteristic movements and reactions are intimately dependent on the peculiar condition known as turgor, which is the expression of the outward pressure of the dissolved molecules of the cell-contents against the membranes which enclose them and which they can not pass. The diffusing molecules hence press against these membranes, often with the force of many atmospheres, and keep the cellulose cell-walls stretched and rigid. It is on this condition that the maintenance of the normal form often depends. The entrance of the water into the cell in growth is also largely due to this osmotic pressure. Thus the confinement of the molecules within the cells by membranes impermeable to their outward diffusion is an indispensable condition of the continuance of normal life-processes in these organisms. The same is true of animal cells, although here the condition of turgor is usually unimportant in itself. But, as we have already seen, the preservation of the normal protoplasmic composition in the case of any cell involves the prevention or restriction of any free or unselected diffusive interchange of materials between the cell and its surroundings. The semi-permeability found during life is the expression of the all-importance of this condition. We must therefore ascribe to the insulatory or semi-permeable character of the plasma membrane, not only the existence of conditions like turgor in plants, but even the very possibility of the existence of a stable or permanent chemical organization in any cell.

This being the case, it is not surprising to find that simple modification of permeability may profoundly modify many cell-processes. To take first a relatively simple instance: if the semi-permeability of the plasma-membrane is a necessary condition for continued life in any cell, it ought to be impossible to increase this permeability beyond a certain limited degree for any length of time without inflicting permanent in-

jury on the cell and eventually causing death. Loss of essential cell-constituents through the altered membrane would have this effect. Now there is evidence that a large class of injurious or toxic substances exert their destructive action by altering the surface-films of cells and permanently increasing the permeability. When this occurs in such a cell as a blood-corpuscle or a sea-urchin egg—which is normally in osmotic equilibrium with its medium—the cell first swells (an effect showing loss of osmotic equilibrium) and eventually dissolves or disintegrates, an effect known as cytolysis. Lipoid-solvents, like chloroform or ether, have this effect in concentrations above certain minima: they disrupt the membrane, presumably by altering the condition of the lipoids, and disintegration follows. Many toxic alkaloids and glucosides—like saponin, digitalin, aconitin, etc.—and certain bacterial products—cytolysins and hemolysins—have similar effects. Other substances, as inorganic salts, acids, or alkalis, may cause cytolysis by altering the state of the colloids of the membrane. In certain typical instances there is direct evidence that the toxic action is primarily due to a surface-alteration, and consists in a destruction of the semi-permeable properties of the membrane. Certain fluorescent substances like eosin exert a cytolytic action on many cells in the presence of light, though inactive in the dark (photodynamic action). Harzbecker and Jodlbauer found that blood-corpuscles so treated began to swell before there was any perceptible entrance of the dye into the cell, *i. e.,* the initial stage of cytolysis, involving a loss of osmotic equilibrium, occurred previously to the entrance of the toxic substance. But loss of osmotic equilibrium, unless soon reversed, involves destruction of the cell. The essential or critical toxic action in this case is thus superficial, and what is true of eosin is probably true of many other—possibly most—cytolytic substances.

The peculiar antagonisms existing between the physiological actions of various substances (*e. g.,* muscarin and atropin, toxin and antitoxin, etc.) are probably in many cases to be explained on this basis. The toxic and antitoxic actions of neutral salts form a case in point. Pure solutions of sodium salts, even sodium chloride, are strongly toxic to many cells, particularly those of marine organisms, as the work of J. Loeb and his successors has shown with especial clearness; but if to the pure solution a little calcium salt is added, this toxic action is prevented or greatly diminished; the calcium (or other favorable salt) counteracts the toxic action of the sodium salt—in other words, has an antitoxic action. Now it can readily be shown in certain organisms that the toxic action of the pure sodium salt solution is associated with a strong permeability-increasing action. As test-objects or physiological indicators in the investigation of these effects I have used the pigment-containing eggs of the sea-urchin, *Arbacia,* and the larvæ of a marine annelid, *Arenicola,* whose cells contain a water-

soluble yellow pigment. The eggs or larvæ die rapidly in pure isotonic solutions of sodium salts, and this toxic action is associated with a loss of pigment (more or less rapid according to the particular salt employed), *i. e.*, with a marked increase in permeability. But if a calcium or other antitoxic salt is previously added to the solution, both the permeability-increase (as indicated by loss of pigment) and the toxic action are prevented or greatly retarded. Apparently, a pronounced and persistent permeability-increasing action is equivalent to a toxic action; the calcium prevents or retards this destructive action of the sodium salt on the plasma-membrane, and hence has an anti-cytolytic or antitoxic effect. Professor Osterhout's experiments disclose similar conditions in plant cells; pure solutions of sodium chloride increase permeability—as shown by loss of turgor and increase of electrical conductivity—and have a well-marked toxic action; both of these effects may be prevented by adding a little calcium to the solution. In all of these cases the antitoxic action apparently consists in protecting the surface-film against the permeability-increasing action of the pure sodium salt solution. I have found that not only salts of metals, like calcium and magnesium, but also various lipoid-solvents or anesthetics may prevent the cytolytic action of pure solutions of sodium salts in an essentially similar manner. Evidently certain changes in the state of the lipoids in the membrane render the latter more resistant to the disruptive action of the salt solution. Cytolysis by substances like saponin may also be checked by neutral salts. It seems probable that the relations between bacterial cytolysins and anti-cytolysins are of the same essential nature. The theory of antagonistic salt-actions may thus become of the greatest importance as a guiding principle in practical therapeutics. Such surface-actions as those just described constitute only one form of toxic action, but they are among the most important because of the external position of the plasma-membrane in the cell and its consequent direct accessibility to modification by changes in the surroundings.

The integrity of the plasma-membrane thus appears to be essential to the normal living cell. Injury to this membrane thus means toxic action: prevention of this injury is antitoxic action; restoration of the normal permeability after injury is therapeutic action. But the plasma-membrane does not play only the purely passive rôle so far indicated. It is intimately concerned in many active cell-processes; and there is evidence that many of the distinctive energy-manifestations of the cell are determined or controlled by changes—largely changes of permeability—which have their seat in this structure. This appears to be true of many forms of cell-movement, of cell-division, and of the stimulation-process in general. Permeability-changes are also concerned in secretion, in the fertilization of the ovum, and probably in the general process of intake of food-materials by cells. The stimulation of irritable tissues is a process which exhibits a peculiarly intimate dependence on

the semi-permeable membranes of the irritable elements. Perhaps more is known of the relations of membranes to the stimulation-process than to any other cell-activity, and I shall accordingly consider its conditions in some detail.

There is evidence that a rapid and reversible increase in the general permeability of the plasma membrane is an accompaniment and indeed a primary condition of stimulation in irritable tissues. This evidence comes from many sides and is partly direct and partly indirect. Perhaps the clearest indications of this kind are afforded by the motile mechanisms of certain plants, like the sensitive plant (*Mimosa pudica*) or the Venus's fly-trap (*Dionæa*). In *Mimosa* the characteristic movement, which consists of a dropping of the leaves and a folding together of the leaflets, is due to a collapse of certain turgid cells which form the so-called pulvini, or cushion-like masses of parenchyma at the bases of the leaves and leaflets. A fluid containing dissolved substances rapidly leaves these cells on stimulation; evidently the membranes, semi-permeable during rest, become suddenly permeable to the osmotically active intracellular substances which maintain the turgor. This explanation—first put forward in its essentials by Sachs—is accepted by the majority of plant physiologists, and there is little doubt of its substantial correctness. We have here, therefore, an instance where stimulation depends directly upon a sudden increase in permeability. Now in this case the primary or critical change is apparently the same as in irritable animal tissues; an electrical variation similar to that shown by an active muscle or nerve accompanies the movement, and the conditions which call forth the response are essentially the same in the plant as in the animal. In the case of animals the evidence that increase of permeability is a condition of stimulation is, as a rule, less direct. Yet in certain organisms a sudden increase of permeability may readily be shown to be the equivalent of stimulation. My own observations on the pigmented larvæ of *Arenicola* illustrate this very clearly. When these organisms are suddenly brought from sea-water into pure isotonic solutions of sodium salts (*e. g.*, *m*/2NaCl) the muscles contract with extreme vigor and persistency, causing the larvæ (which are small worm-like trochophores about 0.3 millimeter long) to shorten to half their normal length; at the same time the yellow pigment contained in the cells of the organism diffuses into the solution and colors the latter yellow. The exit of pigment is the expression of a rapid permeability-increasing or cytolytic action; this is equivalent to a strong stimulation. If by the addition of any substance to the solution we check or prevent this permeability-increase, we find that stimulation is checked or prevented at the same time. Thus, if instead of the pure *m*/2NaCl we use *m*/2NaCl to which a little calcium or magnesium chloride, or other appropriate salt, has been added, the strong stimulation and loss of pigment are no longer seen—both are simultaneously

prevented. The same effect may be produced by various anesthetics; these also protect the cells against the permeability-increasing action of the *m*/2NaCl, and at the same time prevent stimulation. Thus, if *Arenicola* larvæ are exposed for a few minutes to an isotonic solution of a magnesium salt and are then brought into *m*/2NaCl, neither stimulation nor loss of pigment follows. The same is true if they are brought from ether-containing sea-water into ether-containing *m*/2NaCl; and other anesthetics in appropriate concentrations show a similar inhibitory and protective action. These and similar experiments point to the conclusion that a membrane-alteration, in the direction of rapid increase of permeability, is constantly associated with stimulation. It is of course apparent that such increase in permeability must in normal stimulation be perfectly reversible. If the reversibility is incomplete, permanent injury results; and this is in fact the case when *Arenicola* larvæ are stimulated by immersion in pure isotonic sodium salt solutions. We have already seen that this injurious action, as well as the stimulating action, is greatly diminished by the presence of calcium chloride, or some other antitoxic salt. Anesthetics also show an antitoxic as well as an anti-stimulating action.

It is impossible within the limits of this article adequately to discuss the physiology of stimulation. A few of its aspects ought, however, to be touched on here, since otherwise the above relation between permeability-increase and stimulation may appear as a merely empirical or detached observation, without any general or theoretical significance. The most striking physical peculiarity of irritable tissues is their sensitivity to electrical changes in their surroundings. Most persons are accustomed to think of electrical currents as laboratory phenomena *par excellence,* and as playing little part in nature outside of laboratory walls. Yet living cells are profoundly influenced by such currents. We can in fact imitate the normal conditions more closely by using electrical currents as stimuli, than in any other manner. This preconception is however a completely mistaken one. Not only do irritable tissues respond to electrical currents, but certain electrical changes in the tissues themselves are invariably associated with stimulation, whether normal or artificial, and form perhaps the most constant and essential feature of the stimulation-process. Such a statement may sound like a truism to any one versed even slightly in modern physical chemistry: ions—charged molecules and atoms—are present everywhere in protoplasm, and it would perhaps be surprising if electrical changes did not accompany protoplasmic activities. We have, however, to inquire more particularly into the nature and conditions of the response of irritable tissues to the electrical current, and of the electrical processes originating in the tissues themselves, and to relate these processes, if possible, to the total effects produced by stimulation.

These processes again, like some of those already referred to, appear to be a function of the changing permeability of the plasma-membrane. When we take a tissue consisting of a parallel bundle of cells, like a frog's sartorius muscle, cut it across, place one electrode in contact with the normal uninjured surface of the muscle, and the other with its cut surface, and connect the two with a galvanometer, we find that an electrical current passes—the so-called demarcation-current. The exposed interior (or cut surface) of the cells always shows a lower potential than the exterior; the potential-difference lies usually between a tenth and a twentieth of a volt. This potential-difference depends on the living condition of the cells. It is absent or insignificant in dead muscle. It diminishes when the muscle-surface is treated with cytolytic substances—*i. e.,* with substances which increase the permeability of the plasma-membrane. The evidence, in fact, indicates that the existence of a normal demarcation-current potential is dependent on the semi-permeability of the plasma-membrane. When the permeability is artificially increased, the potential-difference is invariably diminished; its degree thus appears to be dependent on the degree of permeability of the membrane; hence its increase on death or under the influence of membranolytic substances. Now during stimulation the demarcation-current potential always undergoes a marked decrease; this is the change known as the negative variation or action-current, which is an inseparable accompaniment of stimulation. Normally, this change is completely reversible, and when stimulation ceases, the original potential-difference is regained. What is significant from the present point of view is that the *direction* of the electrical variation accompanying stimulation is the same as in that resulting from death or cytolytic action and associated with an increase of permeability. The phenomenon is thus intelligible on the assumption that during stimulation there is a sudden and marked increase in the permeability of the plasma membrane. This permeability increase, with the accompanying electromotor variation, differs from that associated with death or cytolysis chiefly in being rapidly and completely reversible. Stimulation may, however, be so excessive under some conditions as to lead to irreversible alterations in the membranes, or even to the death of the cell; *i. e.,* the degree of reversibility is limited, and this consideration explains why excessive stimulation is so injurious—it is in effect equivalent to a cytolytic action or any other action where permeability is irreversibly increased.

Why should a change in the permeability of the membrane produce electrical effects of this kind? The phenomenon becomes intelligible when we remember that membranes act by limiting or preventing diffusion, and that they may limit the diffusion of ions—the mobile, electrically charged atoms and atomic groups present in salt solutions—just

as they do that of uncharged molecules. The ions formed by the dissociation of any electrolyte have as a rule unequal diffusion-velocities, and presumably unequal solubilities and other physical properties, in correspondence with their chemical differences; and hence we may infer that they possess unequal abilities to pass through membranes. If this is so, a membrane separating two electrolyte-solutions becomes the seat of a potential-difference; *i. e.,* a potential-difference, which may be considerable, will exist between its opposite faces. This suggestion, first made by Ostwald in 1890, has formed the basis of the chief prevailing view—the so-called "membrane-theory" of the nature of the bioelectric processes. Ostwald's suggestion, modified to suit the conditions in cells, was essentially as follows. Imagine the cell enclosed in a plasma-membrane freely permeable to the cations (positive ions, *e. g.,* hydrogen ions or potassium ions) and impermeable to the anions (negative ions) of a certain electrolyte (which we may suppose to be lactic or carbonic acid) contained in the protoplasm (Fig. 2). The cations then pass outward, carrying their positive charges, while the anions remain behind; this will proceed until the potential-difference thus arising is sufficient to compensate the diffusion-tendency (equivalent to the osmotic pressure) of the cations. A condition of equilibrium with outer surface positive and inner negative thus results. The membrane becomes the seat of an electrical polarization (normal or physiological polarization) which is dependent on its impermeability to anions. If the permeability of such a membrane were to increase sufficiently to transmit the anions, a fall of the potential-difference between the exterior and the interior of the cell would at once follow. An effect of just this kind is seen in muscle and nerve during stimulation, and is attributed by Bernstein and other upholders of the membrane-theory to the changing ionic permeability of the membrane. The selective permeability to ions of different sign, on which the potential-difference between exterior and interior depends, disappears along with the general increase in permeability accompanying stimulation: hence a negative electrical variation is always associated with this process.

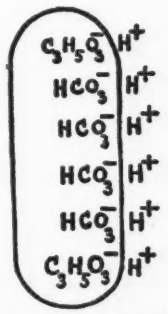


FIG. 2. Illustrating the supposed conditions of polarization of the plasma membrane. The electrolytes are lactic and carbonic acids; the membrane is supposed to be permeable only to H-ions.

The precise arrangement imagined by Ostwald has not yet been satisfactory realized, although, according to Brünings, precipitation-membranes of copper ferrocyanide show some of the properties required by this theory. But certain natural membranes present a much closer approach to the theoretical requirements; thus the surface-membranes of apples, which Beutner and Loeb have recently studied, behave as if

decidedly more freely permeable to cations as a class than to anions, and it is possible that this condition is typical for the plasma-membranes of cells. The membranes of irritable tissues, however, may belong to another type; certain membranes (consisting of thin films of glass) whose electrical polarization depends on the relative hydrogen-ion concentrations in the solutions which they separate, have recently been investigated by Haber; and in some respects the phenomena presented by these membranes appear to correspond more closely to the conditions in irritable tissues. Hydrogen-ions would be the polarizing cations in the case of these membranes; and in fact irritable tissues are as a rule remarkably sensitive to changes in the H-ion concentration of their medium. We are not yet in a position to decide between such alternatives. But for the present purpose it is sufficient to recognize that a membrane which interferes unequally with ionic diffusion may become the seat of a potential-difference when it separates two solutions; and the evidence that plasma-membranes and other cell-membranes are of this kind appears very strong, even at the present time. In general, phase-boundaries are the seat of electrical energies, and these largely depend on the ionic content of the adjoining media. Membrane-polarization is a special instance of this general class of phenomena. The precise conditions of the normal physiological polarization in irritable tissues have to be determined by future investigation.

Membranes in their electrochemical aspect are to be regarded, on the present theory, as *ion-transmitting* surfaces, just as the metallic plates in ordinary electric batteries are ion-forming or ion-combining surfaces. The electrical properties exhibited by all of these surfaces are conditioned in essentially the same manner, and Nernst's theory applies to all. A system composed of solutions separated by membranes may thus, under the proper conditions, show the same essential properties as a system of batteries connected in series. The potential-differences of the individual elements may be summed by appropriate arrangement so that the electric tension between the terminals may be very large. In the electrical organs of *Gymnotus* and other fish, systems of this kind have actually been realized in nature, and have been applied to defensive or other purposes.

Let us now consider in a little more detail the conditions of stimulation of an irritable tissue by an external electric current. The surface-film of the muscle-cell or the nerve fiber is to be regarded as electrically polarized in the sense already indicated. Why does the tissue respond in its characteristic manner to the electric current? The first fundamental suggestion as to the mode of action of the current was made by Nernst in 1899. He pointed out that the current in passing through a living tissue—a system equivalent to a solution containing electrolytes and subdivided by semi-permeable membranes—

can produce decided changes of condition only at the semi-permeable surfaces, where the movement of ions is blocked; changes of electrical polarization would be produced at such surfaces; ions of a given sign would be carried against one face of the membrane by the current and would concentrate there until the back-diffusion equalled the current-transport; the same effect, with the signs of the ions changed, would result at the other face (Fig. 3). He conceived that in electrical stimulation something of the kind occurs. The essential or critical change occurs at the semi-permeable membrane, and consists in carrying to this membrane sufficient ions to produce a given ionic concentration-difference corresponding to a given electrical polarization. This is the determining condition of stimulation. A certain time will be required for the process, depending on the strength of the current, and on the specific diffusion-rate of the ions. Nernst estimated that on this hypothesis the stimulating action (S) of a given current ought to vary directly with its strength (i), and with the square root of its duration (t) ($S = Ki\sqrt{t}$, K being a constant characteristic of the tissue). The experimental data show that a more intense current requires for stimulation a shorter time than a weaker current, and in approximately this proportion. The more recent work of Lapicque, Lucas and Hill has confirmed and amplified Nernst's theory. There is therefore strong evidence that a current stimulates by producing an electrical polarization at the membranes.

FIG. 3. Illustrating the polarization of the current on a membrane difficultly permeable to ions. The anions and cations of the electrolyte, NaCl, move in the direction indicated by the arrows. The current, passing from left to right, carries cations toward and anions away from the left face of the membrane; at its right face the conditions are reversed. The membrane thus becomes electrically polarized, with its left face at the higher potential.

During life, however, the membranes are apparently already the seat of a preexistent polarization, as we have seen. The polarization produced by the external current must, therefore, modify this. Now it appears that in most, if not all irritable tissues, stimulation results when the physiological polarization is *diminished* suddenly, but not when it is increased. This is the simple inference from the law of polar stimulation. When a current is passed through a tissue the external positivity of the irritable elements is lowered on the side directed toward the cathode and increased on the side directed toward the anode, as may be seen by reference to Fig. 3. Now it has long been known that the stimulus originates on the cathodal side of an irritable tissue when the current is made, and on the anodal side when

the current is broken; *i. e.*, we obtain stimulation when the preexisting polarization of the irritable elements is rapidly *diminished*—in other words, when there is a *depolarization.* We may formulate the essential relations thus: stimulation is equivalent to depolarization, *i. e.*, to a rapid decrease of the already existing or physiological polarization of the plasma-membranes.

Stimulation, however, is also connected with a change in the permeability of the membrane, as we have seen. We must therefore conclude—since a sudden change of polarization stimulates—that simple alteration of the electrical polarization alters the permeability of the membrane. Decrease of the potential-difference between the opposite faces of the membrane—*i. e.*, depolarization—apparently increases permeability, and often to a remarkable degree. Irritability seems, in fact, to be an expression of this peculiar relation. The electric current thus alters the polarization of the semi-permeable membranes of the irritable tissue, and in so doing alters the permeability. This change becomes the condition of the characteristic electrical variation of the tissue; the latter is self-propagating, and thus the effects of the local stimulus are transmitted to other regions of the cell. These appear to be the essential changes in the stimulation-process as such.

According to this point of view we must conceive of the plasma-membrane of an irritable element as possessing during rest a characteristic impermeability or semi-permeability to which corresponds a definite polarization, or potential-difference between its outer and inner surfaces, of the value of (*e. g.*) one tenth volt. Now the permeability of the membrane is determined by a number of conditions, some of which are, its chemical composition, the temperature, the chemical changes in the protoplasm and the surroundings, and probably the state of mechanical tension of the membrane. Another factor is, however, of fundamental importance: this is the existing state of electrical polarization of the membrane. Alteration of this polarization alters the permeability; if we decrease it we increase the permeability and stimulation may follow; if we increase it we presumably alter the permeability in the inverse direction—hence in all probability the lowered irritability at the anode (anelectrotonus) during the passage of a constant current through a muscle or nerve. Such a view ascribes peculiar properties to the plasma-membrane, but the facts lead directly to this interpretation. Girard has shown experimentally that changing the electrical polarization of a membrane of bladder or parchment alters the permeability to neutral salts. The electrical state of a membrane may thus determine its permeability. The plasma-membrane of irritable tissues has apparently acquired extreme sensitiveness to changes in its electrical polarization, such that slight electrical dis-

turbances in the surroundings may lead to a large increase of permeability, and hence to marked stimulation.[1]

On this hypothesis we can also understand why the state of excitation is transmitted from one region of the irritable element to another. It is highly probable that the effect of a local stimulation is propagated over the surface of the muscle-cell or nerve-fiber because of the electrical variation which the permeability-change at the excited region itself produces. This electrical variation affects the adjacent regions of the membrane, and alters their permeability, with corresponding electrical effects, and so the effect spreads. The explanation of the conduction-process in a nerve or other irritable tissue is on this view identical with that of the stimulation-process. There is, in fact, good evidence that the region in a state of excitation simply excites the adjoining regions electrically by means of its action-current, and that the effect is transmitted in essentially this manner.

It is possible to change the polarization of the membrane, and hence its permeability, in other ways than by passing an electrical current. Or we may alter the permeability directly, by acting on the cell by chemical substances, or by suddenly changing the temperature, or by mechanical action. When such treatment produces a sufficient increase of permeability, we may suppose that all ions become free to pass the membrane, and that a polarization-change then occurs, with consequent stimulation which, like other forms of stimulation, is self-propagating. On such a view the ordinary forms of mechanical and chemical stimuli are at bottom electrical in their nature. Such stimuli act by directly altering the permeability of the membrane and hence its electrical polarization.

On the other hand, the properties of the membrane may be so modified under certain conditions that it fails to respond to changes of polarization by changes in its permeability. This occurs, for instance, in narcosis. I have found that narcotics, in the concentrations at which they anesthetize the musculature of *Arenicola* larvæ, also check or prevent the permeability-increasing action of isotonic sodium chlo-

[1] The assumption of a permeability-increase at the time of stimulation is the only hypothesis, so far as I know, that accounts at once for the two characteristic and invariable accompaniments of stimulation, (1) the negative electrical variation, and (2) the temporary loss of irritability (refractory period) during the electrical variation. The time-relations of these two outwardly diverse phenomena coincide, as Tait has shown, and both are to be regarded as expressions or consequences of the same change, namely, a temporary increase in the permeability of the limiting membranes. This increase involves a temporary loss of the semi-permeability which is essential to the maintenance of the normal polarization of the membrane, and also—according to Nernst's theory—essential to electrical stimulation. I therefore regard the existence of a refractory period as furnishing strong support to the general theory of stimulation and conduction outlined above.

ride solution on the pigment-containing cells of this organism; at the same time they decrease or prevent the stimulating action of this solution. They also protect the organism against its toxic action, as we have already seen. An anesthetic action is thus the equivalent of both an anti-stimulating and an anti-cytolytic action. Both effects depend upon a modification of the plasma-membrane; under the influence of the anesthetic this structure becomes more resistant than normally to conditions that otherwise increase its permeability. We may infer in general that the degree of responsiveness of an irritable tissue is dependent on the state of its plasma-membranes; and that anesthesia corresponds to a condition of decreased susceptibility, and hyper-irritability to one of increased susceptibility, to the action of permeability-increasing agencies. Sensitization and desensitization, on this view, are primarily surface effects, dependent on alteration of the limiting membranes.

The polarization-changes accompanying stimulation may be extremely rapid in some cases. During the contraction of a man's voluntary muscle under the influence of the will, the existence of a rhythmical electrical variation with an average rhythm of about fifty vibrations per second has recently been demonstrated by the thread-galvanometer. The negative variation accompanying a single muscular twitch occupies from one hundredth to one two-hundredths of a second in a frog's voluntary muscle at ordinary temperatures; that accompanying a single nerve impulse lasts about one thousandth of a second; while more slowly reacting tissues, like heart-muscle or smooth muscle, show correspondingly slower electrical variations. On the membrane-theory the corresponding permeability-changes in the membrane must occupy similar times; and this consideration indicates the extreme delicacy of the adjustment between permeability and electrical polarization that must exist in the membranes of highly irritable tissues.

The electrical phenomena of stimulation are, however, relatively inconspicuous—if we except the case of the electric eel or torpedo. The characteristic and biologically important "response" of the tissue varies with its special nature. A muscle contracts, for instance; a gland secretes. The relation between the rapid change of polarization, which is the primary event in stimulation, and the resulting mechanical and chemical effects remains to be inquired into. The problem is a difficult one, and insufficiently investigated. The energy of muscular contraction is derived from the oxidation of energy-yielding compounds, like sugar. We must conclude that the polarization-changes at the cell-surface influence the chemical processes in the muscle-cell. Stimulation is known to increase many times the rate of oxidation in muscle-cells. I have lately attempted to modify the rate of formation of indophenol (a deeply colored organic oxidation-product) in the blood cor-

puscles of the frog by passing induction-shocks; and I find that the rate of formation of this compound through intracellular oxidation can be greatly accelerated by this means, especially in leucocytes, where the oxidation-rate is relatively rapid. I am inclined, therefore, to attribute to the variations in the electrical polarization of the membranes an important general rôle in varying the rate and possibly the character of the energy-yielding intracellular oxidations. On this view, intracellular metabolism would be largely controlled by membrane-processes. How this is possible may be illustrated by the case of anesthesia just discussed. The ether-impregnated plasma-membrane is relatively unaffected, as compared with the normal membrane, by isotonic sodium chloride solution; and consequently the stimulation, with its resultant increase in oxidation, is prevented by thus altering the membrane. The precise nature of the conditions in these and similar phenomena can be elucidated only by further study.

I had hoped to discuss the rôle of membrane-processes in other cell-activities, such as fertilization, cell-division and development, but the space at my disposal is insufficient. Before closing, however, I wish to refer briefly to the large class of physiological processes in which a regular rhythmical repetition of the same change, *e. g.*, contraction, is the essential characteristic. Such processes include ciliary activity, the action of contractile vacuoles, the action of the heart and of nerve-cells like those of the respiratory center or the heart-ganglia of certain animals. In the division of cells during early development, a definite though slower rhythm is also seen. Now an electrical rhythm accompanies the physiological rhythm in muscle and nerve cells, probably in cilia, and almost certainly in dividing cells, as indicated by the experiments of Miss Hyde on dividing fish-eggs. The existence of a chemical rhythm—of carbon dioxide production—has been demonstrated in dividing cells (sea-urchin eggs) by Dr. Lyon, and we may infer its presence in the other rhythmical processes. The electrical rhythm indicates a rhythm of changing permeability, and of this there is some direct evidence in dividing egg cells. In all of these cases we have to do with automatic processes whose rhythm proceeds of its own accord, provided the external conditions remain normal. Each cycle in the rhythm furnishes itself the conditions for its own recurrence. The question arises: from what physico-chemical point of view is it best to regard this class of phenomena? In the case of a rhythmical contractile tissue three interdependent and synchronous rhythms may be distinguished—a chemical, a mechanical (presumably the expression of surface-tension changes), and an electrical. An elementary model of these phenomena is, I believe, furnished by the experiments of Bredig and his pupils on the rhythmical catalytic decomposition of hydrogen peroxide in contact with metallic mercury. When a ten per cent. solu-

tion of hydrogen peroxide is poured over the surface of pure mercury, a film of peroxidate at once forms over the surface of the metal. Its formation alters the surface-tension of the mercury by changing the potential-difference between the metal and the solution. Consequently, the form of the mercury-surface changes. Under appropriate conditions this deformation causes a mechanical rupture of the film at some portion of its surface; there follows on this an electrolytic decomposition of the peroxidate at the margin of the fissure, an effect which spreads over the whole surface and involves the dissolution of the film, and its reduction to metallic mercury, together with the liberation of oxygen. The film then reforms, and the process is repeated. Thus a regular rhythm, involving a form-change, a chemical decomposition, and a change of electrical polarization, is started and continues automatically. The rate of rhythm may be altered, just as in organic processes, by altering the chemical character of the medium, *e. g.*, by changing its alkalinity, or by the addition of various other chemical substances. The velocity with which the film is laid down and dissolved may thus be influenced, and the whole rhythm correspondingly affected. Graphic records showing the variation in the rate of oxygen-liberation present a marked resemblance to the records of rhythmical organic processes like the heart-beat. Now the general conditions determining the rhythm in this phenomenon are strikingly like those which, on the foregoing theory of stimulation, determine the physiological rhythms. The surface-film of peroxidate may be compared to the plasma-membrane. Its rupture is equivalent to a local increase of permeability. This change is the direct condition both of the chemical change and of the electromotor change, on which last depends the variation of surface-tension conditioning the form-change. While the living system is indefinitely more complex than the mercury-peroxide system, yet in its rhythmical character and in the essential nature of the controlling conditions this automatic rhythmical catalysis bears an undeniable and striking resemblance to the action of living tissues like the heart, in which a rhythmical autostimulation is the distinguishing characteristic. In both cases an alteration of a surface-film is the critical change; and the rate of this change determines the rate of the other rhythmical events of the cycle. We may infer that if we could control the condition of the plasma-membranes of cells we could control the entire range of cell-processes. But I do not wish to prejudge these questions; I make the above comparison chiefly in order to suggest possibilities, and to indicate the desirability of devoting more careful study to the surface-films of cells. Investigation of the conditions of their formation, their permeability and their physical and chemical nature is certain to lead to results of far-reaching importance for biology.

THE PROBLEM OF THE EFFICIENCY OF LABOR

By HOWARD T. LEWIS, M.A.
HIRAM COLLEGE, HIRAM, OHIO

IT may truthfully be said that industrial evolution is little else than the progressive development of economic efficiency, and the various stages in the story of the evolution of industrial society have been largely based upon man's control over nature as indicated by his industrial efficiency. The transition from one stage to the next has ofttimes been imperceptible; at others it has been very marked. The modern period, with its great aggregations of capital and its machine-made products, is so far superior to the handicraft stage that comparisons are made merely for the sake of measuring that development. Yet even before we are thoroughly accustomed to the change, significant facts are presenting themselves which would seem to indicate that we are on the verge of still another era of industrial expansion. And though it is always rash to prophesy, yet it may be safe to say that the effect of this transformation upon society in general and especially upon the relation of employer to employee, will be far greater than we may at first think. This much at least seems certain, that tremendous strides are about to be taken *from a purely productive point of view* which will at the same time materially affect the condition of the working classes.

If we eliminate from consideration the element land, and we may safely do so in the present discussion, the production of wealth is the result of two factors, labor and capital, both of which are more or less variable in character. The development of modern power-driven machinery has in recent times been remarkable, and no one would for a moment maintain that the end is in sight. Greater care in the construction and location of mechanical devices already invented will immensely increase their efficiency. Yet it is very questionable if in the future any such radical changes will occur as were witnessed between 1750 and 1850. Perhaps, indeed, it was because of that progress that attention has been in the past chiefly centered upon man's control over nature through the means of mechanical devices. Be that as it may, this much can scarcely be contravened, that those engaged in the active work of production (as well indeed as many theorists) seemed until very recently to have forgotten that capital in the form of machines is only one of the factors upon which the production of wealth depends.

The reason for this undue emphasis is not far to seek. As has been suggested, the enormous strides which have been taken in the invention and development of various forms of power and of labor-saving machinery has in itself, no doubt, been a potent reason why the labor factor should temporarily be neglected. Moreover, the universal confusion among practical men of affairs between labor and capital undoubtedly helped to obscure the importance of the former. Even to-day the manufacturer is prone to place his labor supply in the same category as his supply of raw materials, and to think no more about it than to be sure that there are men enough to run his machines and to do the work demanded. To the consideration of the relative cost and efficiency of two machines he will give hours; to the choice of men to run the machine he will devote scarcely ten minutes. It is these and similar facts that have lain at the bottom of the failure to appreciate properly the importance of efficiency of *labor* as contrasted with the efficiency of machines. Not that labor unions and the backers of progressive labor legislation have been negligent, but their work lies in the main within the scope of the last half or even quarter century, and their labors are just beginning to bear full fruit. As one of our great railroads says to its employees in a recent bulletin:

> There are so many things of the past, so many things of the present, to persuade us to the opinion, if not indeed to the assumption, that man has been so intent upon improving and developing and helping toward perfection the things over which he was given dominion in Eden that he has left the matter of his own intelligently directed evolution until the last.

The result of all this has been that even up to the present, though to the standardization of nearly everything in the mineral and vegetable kingdoms and a goodly portion of the lower orders in the animal kingdom men have worked with earnest and often enthusiastic cooperation, when it came to standardizing *men* and developing efficiency in them, there has existed a confusion and lack of cohesion equal to that of Babel. Efficiency in machinery has been taken for granted by those interested in production, efficiency in labor has been largely overlooked until the modern efficiency engineer appeared upon the scene.

But times are changing, and men generally are slowly coming to realize the full significance of the term "labor efficiency." Part of this has been due unquestionably to the influence of labor unions. The increasing stress given by economists upon the distinction between labor and capital, as economic concepts, has not been without its effects. The natural and inevitable failure of mechanical invention to keep abreast of the pace set at the outset of the industrial revolution has also served to detract attention from the purely mechanical aspect as soon as something else arose which demanded attention. To all this we must add the exhaustion of the frontier and the other influences

called attention to by Professor John R. Commons, which tend to strengthen and emphasize the labor problem generally.[1]

A moment's reflection will reveal the significance of this modern movement toward greater efficiency. When we realize that according to experts *only from 20 to 60 per cent.* efficiency has up to the present time been secured in the average industrial plant we are almost staggered when we think, not only of the effect that has been wasted in the past, but of what will be possible in the future when this energy is rightly directed in the actual work or production. In fact, it would seem that, were one half the effort and thought we make to secure efficiency in things outside of ourselves directed toward the securing of greater efficiency of human units, there would evolve within a few generations a race almost of supermen. So with the rise of those whose business it is to secure efficiency from *labor*—whose specialty is the gaining of cooperation, frankness and well-directed efforts through a study of what has been called "shop psychology" it is wholly possible, if not indeed probable, that a combination with mechanical efficiency may be affected that may well alter the entire aspect of industry, and, mayhap, usher in a new stage in industrial evolution.[2]

Treatments of industrial efficiency up to the present time have, in the majority of instances, been lacking for one of two reasons, either they have overlooked the very human instincts of the employer or they have assumed an inherent antagonism between the interests of the laboring class, as typified in unionism, and efficiency systems that could not be overcome. Let us examine efficiency systems from the point of view of these facts.

The apathy (or active opposition in some instances) on the part of many employers to modern systems of industrial efficiency may be traced to one of two causes. On the one hand, there frequently exists a confusion between low *individual* wage cost with low *total* wage cost. Or, on the other hand, the difficulty that has hitherto existed of measuring with any degree of accuracy the efficiency of individual workmen has undoubtedly worked against a more universal adoption of the plan. Each of these facts will bear some notice beyond mere mention.

The costs of a manufacturing concern may be roughly separated

[1] See also the writer's "Economic Basis of the Fight for the Closed Shop," *Journal of Political Economy*, November, 1912, especially p. 952.

[2] The truth of this statement will appear when the full intent of the measures to develop labor efficiency are considered. The efficiency engineer has more in mind than the mere invention of a new wage system—his work consists equally in securing good housing, relief from monotony, a fair living wage—in a word, in what may be termed social, labor legislation. The fact that he is interested from the point of view of the employer does not alter the significance of his work. More will be said of this later.

into (1) wages, (2) raw material, (3) operating expenses, (4) overhead charges. Taking these four items into account, the producer has, logically enough, proceeded on the assumption that the less he has to pay for any one of them, the selling price remaining constant, the greater will be his net profit. When in the earlier stages of industry, production was carried on in small workshops, and hired help was uncommon because unnecessary, the only direct costs were those for raw material and for overhead charges. The lower the price per unit the producer had to pay, the lower were his total costs of production. When he came to need help in the shop, he assumed, rather than figured it out, that the less he had to pay an assistant per day, the lower would be his wage cost. If the thing were true of raw material, obviously, he reasoned, it would also be true of labor cost. The fact that his help was trained and worked under his personal supervision and hence was actually more efficient than would otherwise be the case probably explains why the fundamental error in his assumption passed unnoticed.

When shops became factories and power-driven machinery replaced the old hand processes, the question of the competency of labor was never raised, for reasons already noted, save in unusual cases, and attention was centered upon capital. With their minds still on the mechanics of production, competing employers began to unite, and the modern concentration and integration of industry commenced. With its development, aided perhaps by those who had the time to analyze theoretically the costs of production, was evolved the monopoly principle of price, namely, that the price should be fixed at that point where the difference between the *total income* and the *total cost* was the greatest. And it was merely a question of time before some progressive individuals came to apply the same principle to wages and the labor cost. The added attention unionism had forced people generally to give to labor undoubtedly caused the idea to develop sooner than it would otherwise have done.

It is, however, in some respects a surprising thing that this principle has not come to have a more general recognition, since it is applicable in industries other than monopolies. In theory, it is almost universally conceded that the efficient man—he who produces most and best—is always the most profitable, even though he demands a somewhat higher wage. The truth of this statement has always been the reason ascribed for the successful competition of American industry with that of Europe, *despite lower wage cost per unit on the continent.* But employers have been prone to accept this greater efficiency of the American workman as a thing in the natural order of events, and so drew the conclusion that if he could get this greater efficiency at European rates, his profits would be doubly increased, failing utterly to see that *the efficiency largely depended upon the higher wage,* or, in

other words, that efficiency and low wage can not, in the very nature of things, be compatible. In America, the higher wage was for a long time a thing the employer could not avoid, but in Europe it could be avoided. The recognition of the principle and its application to practise has hitherto been left to Germany, who has clearly demonstrated in her mills that it is "the improved workman who is accountable for efficient workmanship," and that it is the totality of the effect of this fundamental economic and educational movement that has brought Germany to the front in the present industrial competition. Dr. Eliot has put it:

> We now know that the most efficient labor and the cheapest in proportion to its product is found where the laboring classes live comfortably, are well housed and fed, develop their intelligence and widen their prospects. The cheapest labor is no longer considered the most profitable.

Unfortunately, Dr. Eliot's conclusion is, though inevitable, somewhat premature so far as the United States is concerned, for it is still largely the rule in practise, though not in theory, to confuse low labor cost per unit with low total cost. Happily, the theory is becoming more and more the practise, and it is well, unless we are willing to be hopelessly outclassed by our neighbors in the competition for the world market.

There is, however, another factor, and one for which the employer is not so directly responsible, that assists in explaining why modern efficiency systems are not more universally adopted. This is in the fact that until quite recently no means has been available by which the employer could with any degree of accuracy measure the relative efficiency of men or of various systems of organization. The employer, of necessity, has paid one scale of wages to one class of workmen, because, as a rule, he had no means of gauging the amount of work of each man. It is exceedingly difficult to determine exactly what each of a number of workmen does each day, and even if he does know, the difficulty of comparing them is very great unless the work done by each man was of the same nature and done under the same conditions. The result has been that the employer has kept no individual records, and instead treats all workmen of a class as equals, and pays them the same wage. There may be 20 per cent. who are more efficient than the rest, but he has no means of distinguishing them from the others with any degree of accuracy. The result is that he declines to increase the wages, or makes such increases so small as to be insignificant as compared with differences in efficiency. In hiring men he offers the wage for which he can obtain the cheapest man, and if the good man stands out for a higher wage, he usually gets none at all. If the efficient man is to get a higher wage, his entire class must get it, and then the employer is paying the men more than they are worth. If the efficient

workman be a unionist, he must, if he be consistent, slacken his pace to that of the poorer one's, and hence in such shops the employer usually gets the efficiency he pays for. The question, therefore, which must be settled before all others, if the efficiency scheme is to be adopted, is: how shall differences in efficiency be measured?

Obviously to base a wage scale upon mere personal judgment as to the relative efficiency of men working within a shop would be out of the question, not only because it opens the way for charges of personal favoritism and consequent labor difficulties, but also because the complexity of modern shops would make such a plan physically impossible. The introduction of the simple piece-work plan was hailed as a great advance, as it unquestionably was from certain points of view, but here, too, failure was inevitable. Pace setting with the regular "trimming down" of wage scales was certain to produce bad feeling amongst the men, if no worse evils resulted, which was improbable. The workmen, too, were held responsible for all errors, which is obviously unfair—and bad policy for the employer, besides. Moreover, the plan is based upon a fundamental fallacy, namely, that a just scale of wages based on piece-work can be made which will at all times and under all conditions be just. The universal objection on the part of labor unions to simple piece-work has both theoretical and practical justification.

In view of these facts, modifications were suggested, notably in the Halsey, Rowan, Emerson and Taylor systems.[3] Space does not permit a discussion of the relative merits of these systems, even though it might fall within the scope of this article. Suffice it to say that a scheme had to be devised of accurate, concise individual records that could be used so as to be fair to the employer, yet that should recognize and encourage the good workman while it did not discourage the poor one. This has been done after considerable experimentation by efficiency engineers, and has proven satisfactory. The Holerith Service Requisition card[4] is a fair sample of what can be done along this line, and makes it possible to measure relative efficiency of workmen, not only with each other, but with whatever standard existing conditions justify.

We are now in a position to consider the other side of the question. What is the attitude of the laboring man to these efficiency schemes? It must be admitted that so far as organized labor, at least, is concerned its opposition is almost universal, and that this opposition has been the source of much criticism. Two questions naturally present themselves at this juncture: why does unionism oppose the efforts of the efficiency engineer, and second, what will be the ultimate outcome of such opposition? Let us consider these queries in their logical order.

[3] See Bender, "Systems of Wages and their Influence on Efficiency," *Engineering Magazine*, 26: 498.

[4] See *Engineering Magazine*, 36: 820.

The opposition of unionism to efficiency schemes is based upon two facts; the persistence of bad economic theory and the remembrances of bitter experiences. The theory that the various methods of restrictions of output, such as the refusal to follow pace-setters and the like, will make more work for other unionists has long been held by the ardent union followers, and the Bureau of Labor has said that the idea is almost universal among laboring men, whether members of a union or not.[5] The fallacy of such a doctrine has long since been exposed, and needs no repetition here. A more fundamental error, and possibly the real source of the one just mentioned, is the failure to recognize that wages are paid from total product and that labor's share in the national income is proportional to its share in the production of that income. The old wage fund doctrine still lingers. But unless we do entertain that abandoned theory it is difficult to escape the conclusion that increased efficiency results in added product and a consequent higher wage scale. This much at least is true that, as society is at present constituted, the laborer can not in the long run get more wages unless he also produces more.

Doubtless, however, the chief source of difficulty between the unionist and the efficiency advocate grows out of the experience of organized labor in the past with piece-work, bonus and premium plans; nor can it be said that the unionist is to be greatly blamed for being suspicious. The practical (and it has sometimes seemed almost inevitable) consequences following the institution of these plans in the past are too well known to be repeated here. The horizontal cut in the wage scale following what the employer has termed the earning of "excessive bonuses," time after time has made unionism perhaps unreasonably wary of all like schemes in the future. Be that as it may, this fact remains, that after having been trapped into being compelled to work at a killing pace to earn a decent wage, organized labor, pointing to this experience, objects to the point of desperate struggle the adoption of any form of "wages on the basis of efficiency" without giving them the chance even of a trial. Note the attitude of the Metal Polishers Union at the Rock Island (Illinois) government arsenal toward the introduction of the Taylor cards.

Unquestionably, the crux of the whole matter is in the relation of these efficiency schemes to the laborer and their effect upon him. Some writers have argued that since unionism is primarily interested in high wages, and the employer in low costs of production, that unionism and efficiency are inherently antagonistic. Others contend that because of its persistent fight against it, unionism will eventually compel industry to adopt "democratic measures" just as the evils of standing armies

[5] See Report of Bureau of Labor on Restriction of Output (1904).

compel nations to arbitrate their differences. Still others maintain that the most effective weapon against unionism is the proper reward of efficiency, since by that means all reasonable discontent is quieted. Thus H. L. Gantt in an article noted above says:

> If you keep an exact record of what each fellow does, surround the men with conditions under which they can work at high efficiency and compensate the efficient one liberally, no man will spend his spare time trying to find out how to raise the wages of the other fellow. Workmen as a rule will do more if their earnings are increased by so doing, and you will have great difficulty in getting the efficient ones into the labor unions if they are not benefited by joining.

In passing judgment upon these criticisms, two facts stand out preeminently before the thoughtful student of this question. The first is that some kind of an efficiency system, constructed upon a cost basis, is to become inevitably an integral part of the industrial organization of the future. Men may be apathetic about it, mistakes will be made in its application, labor unions may strive against it, but it is as inevitable as the industrial revolution. Time was—and traces of the spirit still linger—when labor organizations struggled against the introduction of modern labor-saving devices. The Knights of St. Crispan might unite against the use of pegging and sewing machines in the shoe industry; printers might protest against the introduction of the linotype, but it was of no avail—these things were a part of industrial evolution—*they increased man's efficiency in production,* and they could not be stayed. Exactly the same thing is true of modern efficiency systems—attention has been shifted from capital to labor, but the result will be the same. The employer demands it because his profits are thereby increased; the efficient laborer demands it because it increases his compensation and he feels, rightly, that superior skill should be rewarded; and society as a whole demands it, because in its totality it tremendously increases social wealth and welfare. The sooner unionism recognizes this fact and acts accordingly, the better it will be for its cause, both directly and indirectly. For we are loathe to admit that labor and capital are, and must remain, inherently antagonistic.

The second fact that requires recognition is that no plan which tends to increase the dependence of the laborer upon the employer or that fails to take cognizance of the real, vital well-being of the employee can in the long run prove successful. Because of this, it is essential that the employees in their collective capacity be given a voice in the direction of the shop. With human nature as it is, the temptation to cut piece-rates, to speed up machinery, and the utilization of similar methods must be, so far as possible, removed. In time the employers will undoubtedly come to see that the lack of hearty cooperation that

must be expected from men who are driven instead of led will wreak its own evil consequences, but in the meantime something else must be substituted. The details must needs vary with the individual shop and trade. It is necessary, however, that in some manner the employees in their collective capacity be recognized. From this point of view the plans of the Pennsylvania Railroad, the United States Steel Corporation and the National Biscuit Company, who offer a limited stock to their employees at reasonable prices, are weak. Few men can buy a sufficient quantity of stock to insure an effective interest, or if so, they can not hope to exercise the faintest semblance of influence upon the policy of the concern. The plan of the William Filene Sons' of Boston is far better. According to it the employees have a permanent shop committee, with certain privileges of recommendation regarding shop condition, methods of manufacture, and so forth, to a similar committee representing the employers. A combination of these two plans would undoubtedly be still more satisfactory wherever practical. Nothing is better established than that arbitrary, dictatorial methods on the part of the employer are fatal to the real interest and cooperation that an efficiency system demands. Such an attitude can result in nothing else than suspicion and antagonism. Whatever plan be adopted, therefore, it is essential that a channel be provided through which the workmen can express themselves.

It will be seen, therefore, from what has been said up to this time, that the question of efficiency is a far more complex one than appears at first sight. Perhaps, indeed, the efficiency expert is himself not entirely blameless in the matter, in that he has seemingly placed undue emphasis upon some system of *wage payment* and not enough upon the deeper significance of such a reform. For after all the introduction of some new plan for paying wages is but a superficial thing, if considered by itself. True, output may be tremendously increased by artificially stimulating the workmen through some form of piece-work; "speeding" increases output, despite the fact that it also kills men. The permanent, vital results of efficiency schemes appear after a man's wages have been increased as a result of added output. It is the things a man buys with his increased income and the improvement in his environment which it makes possible that constitutes the real basis of efficiency. Additional wages are of no value unless they bring to the earner better food and clothes, better housing conditions, relief from the monotonoy of factory toil, reasonably safe and sanitary places in which to work—in short, unless they mean a higher standard of living.

There is probably no efficiency expert worthy of the name who does not realize all this or who does not appreciate its full significance. It

is probably equally true that he does not strive for these things out of any consideration for the employee, but rather because it increases production. He sees, however, that the one necessarily implies the other. His first step in the attainment of his end has been the invention of a new system of wage payment, and he has been increasingly successful in this direction. But in doing so, he has so far neglected to purposely emphasize the *ultimate* aim that his critics have lost sight of it altogether. The result is that in many instances the unionist fails to understand his motive, and the employer does not see its necessity.

The problem of the efficiency of labor is therefore but a phase of the far wider problem of distribution. What the advocates of labor legislation and reform are striving to do from the point of view of the wage-earner, the efficiency expert is endeavoring to secure, though he may not realize it, from the standpoint of the employer. It would be well if this fact were more generally understood, for then the difficulties would be solved the sooner, and there would be less working at cross-purposes. And, after all, it is as Theodore Roosevelt said recently at Columbus:

> We have no higher duty than to promote the efficiency of the individual. There is no surer road to the efficiency of the nation.

BERGSON'S VIEW OF ORGANIC EVOLUTION

By Dr. HERVEY W. SHIMER
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE French philosopher Henri Bergson has most appropriately chosen as the title of his book on development the name "Creative Evolution." As the name implies, to the inevitableness, the invariability of evolution as developed through physico-chemical laws, this philosophy adds the spontaneity, the indetermination of creation. The English translation of this book by Arthur Mitchell is a masterpiece of such work, and he is to be highly commended for the sympathetic manner in which the translation has been carried through.

All views of evolution divide naturally into two groups, the *mechanistic*—that all life can be accounted for through the application of the laws of physics and chemistry—and the *vitalistic*—that while the laws of physics and chemistry explain much, they do not explain all.

The principal radical views of these two groups are the following:

Mechanistic	**Neo-Lamarckian.**
	Neo-Darwinian.
Vitalistic	**Creative Evolution (Bergson).**
	Teleology.

The Neo-Lamarckians hold that characters acquired during the lifetime of an individual are transmitted to its offspring. The Neo-Darwinians deny this utterly, holding that the germ cell, the reproductive tissue, is set apart for its generative work while the animal is in its embryonic state, that is, the reproductive tissue is not the product of the animal's own soma cells, but of its parents' germ cells. This school of Neo-Darwinians explains evolution by the theory that the germ cells are continually changing in every possible direction permitted by their stage of development and that those of these changes shown forth in the adult animal or plant which are beneficial to the organism are selected by nature for preservation. To the adherents of the former school, environment gives rise to variations; to the adherents of the latter it merely selects. To the former the long neck of the giraffe is due to the necessity that successive generations get their food from higher and higher bushes, a process of stretching illustrated by the animals in Kipling's "Just So Stories"; to the latter, those changes in the germ cell leading to neck elongation in the adult were selected by nature in times of drought.

Teleology in its most radical form holds that life is carrying out a

pre-arranged plan, that at the beginning everything was determined in detail and that all life is now following out the lines of that plan. Comparing this with the other two theories, the rabbits have long hind legs according to the Neo-Lamarckians because of the exercise they received when running to escape the fox; their ears likewise became longer because of the intentness with which they must guard against enemies. To the Neo-Darwinian the elongate ears and hind legs are due to changes in this direction in the germ cell, which changes nature selected by means of the fox who ate all individuals failing to make this change. To the teleologist it was planned in the beginning that as the fox became swifter the rabbit should likewise become swifter and more acute of hearing so that a proper balance should always be preserved between them.

Bergson's view of creative evolution is vitalistic in that it, with teleology, postulates a psychical force, which he calls the life impetus. But it differs from teleology especially in its belief that life is not bound by any prearranged plan, that it is free at all times to modify its course, to change its direction. Life, according to this view, is like a shell bursting as it flies, each fragment again bursting, and so on. The life impetus is thus continually dividing. Just as the way a shell bursts depends both upon the explosive force of the powder and the resistance of the metal surrounding it, so the direction of life depends upon the unstable balance of tendencies which it bears within itself and the resistance it meets with from inert matter. It is as if the vital impetus were trying to graft on the invariableness of matter the largest possible amount of instability.

According to the view of creative evolution, then, environment is a force evolution must reckon with, but not its cause, as with the mechanists, while adaptation of the organism to its environment will explain the sinuosities of the course of evolution, but not the general direction and still less the cause of the movement itself.

The problem confronting this vital impetus as it enters matter is somewhere to gather energy with which to counteract the retarding force of matter. At the surface of this earth the most available source of energy is the sun's rays. So the problem before life was this—to store this energy in suitable reservoirs so that it could be drawn upon at any time and for any need such as movement or reproduction. It succeeded in this by causing the kinetic power of the sun's rays to break up the inorganic compounds into their separate elements and then recombine them into the potential energy of organic foodstuffs. At first, doubtless, an organism thus gathered for itself the energy which it later expended in free movements; this form may be symbolized in a crude way by the infusorian, *Euglena*. This organism expends kinetic energy in motion like any animal, but in addition to the ordinary animal

method of deriving potential energy from plant reservoirs it likewise stores up potential energy for itself by the direct action of the sun's rays on its chlorophyll. But in the course of higher development it was found that these two functions, that of storing up energy and its expenditure in free movements, were incompatible in the same organism. There thus opened out before the organism two lines of development, one of greater movement, but with all the hazard of an uncertain food supply, the other of fixity, but with a certainty of food supply; the former resulted in the animal kingdom, the latter in the vegetable.

Since, however, these two kingdoms are branches of the same life impetus each contains something of the other. The difference lies merely in the tendencies upon which each lays emphasis, while it leaves the other tendencies lying dormant. So that plants and animals can not be defined by mutually exclusive characters, but rather by the accentuation of certain tendencies. Plants take their food as a rule from the inorganic, animals from the organic; as a result plants are usually fastened to the earth, immobile; animals get their food through movement. As a consequence of this differing method of food getting the plant cell surrounds itself with a hard coat of cellulose through which external stimuli can with difficulty affect the organism, and there is hence made possible but a very slight consciousness. Since to the animal cell movement is essential to food getting, it can not completely encase itself in a hard external skeleton; it thus follows that external stimuli readily affect the organism and there is hence rapidly developed an ever higher type of consciousness.

Consciousness, as used by Bergson, is not limited to self-consciousness, but is the kind of consciousness that Jennings in his "Behavior of Lower Organisms" is inclined to believe is possessed by all animals from the highest to the lowest. Bergson relates it to mobility. "The humblest organism is conscious in proportion to its power to move freely."

The elements into which a tendency splits do not possess the same power to evolve. The truly elementary tendencies continue to evolve, leaving behind the residual, split-off tendencies. This is illustrated in the development of the plant kingdom, where it is the carbon-fixers which carry on the main line of evolution.

Along the animal pathway, three of the main branches are those of the mollusks, arthropods and vertebrates. During the middle Paleozoic all had run into the blind alleys of stagnancy, of torpor, since most forms of these phyla had become enclosed in a hard external skeleton; but before this condition had become universal, some of the arthropods assumed, instead of the hard external skeleton of the crustacean, the soft one of the insect, and among the vertebrates the armored fish gave place to the unarmored.

Bergson here makes one of his most suggestive contributions, for he makes intellect and instinct divergent instead of linear characteristics. Intellect is not derived from instinct, but they are both present in all life. The former is emphasized by the vertebrates, reaching its culmination in man; the latter is especially developed by the arthropods and finds its highest expression in the Hymenoptera—bees, wasps and ants. The awakening from torpor could be effected in two ways; life, *i. e.*, consciousness launched into matter, could fix its attention either upon its own movement or upon the matter it was passing through, and it would thus be turned either in the direction of intuition, or of intellect. Apparently, on the side of intuition consciousness could not go far; it found itself so restricted by its envelope that intuition had to shrink into instinct, *i. e.*, to embrace only that portion of life upon which its continued well-being depended. Instinct is a prolongation of the life principle (vital impulse). We call that the life principle which in a living body coordinates the thousands of cells to work towards a common end and to divide the labor of feeding, reproduction and preservation among them, but we call that instinct which causes the bees of a hive to work towards a common end, and to divide the labor of feeding, reproduction and preservation among them.

The most essential of the primary instincts are really vital processes. Instinct only carries further the work by which life organizes matter. When the little chick is breaking its shell with a peck of its beak it is acting by instinct, and yet it merely carries on the movement which has borne it through its embryonic life. When the digger-wasp, *Ammophila,* stings its caterpillar victim in just the right places to ensure paralysis without death it acts by instinct, it must not be considered to have any knowledge like that of the learned entomologist who would know the vulnerable places from the outside—from detailed observations of all parts of the caterpillar body. The insect's knowledge, instinctive, proceeds from its inner identification with the same life principle as that of the caterpillar—from a sympathy (in the etymological sense of the word) between the two organisms which teaches the insect from *within* the vulnerability of its victim, whereas the intelligence of the entomologist goes all around the caterpillar instead of entering into it, making itself one with it.

On the other hand, consciousness concentrating its attention upon the matter it was passing through succeeded in evading the barriers raised by it, and now in man, freed to some extent from matter, it can turn inwards on itself and awaken the powers of intuition which still slumber within it. Intuition as thus used is instinct that has become disinterested, self-conscious, capable of reflecting upon its object.

Bergson makes freedom the corner-stone of his theory. The vital impetus has for its goal the acquirement of an ever fuller volume of

free, creative activity. Man shows that forth in himself in the creation, improvement and pursuit of ideals. He follows no prescribed path; he is perfectly free to choose, except that he may not go contrary to the broad course of evolution, *i. e.*, the direction of flow of the vital impetus.

While consciousness (vital impetus) is thus creation and choice, it is also memory. Beings advance in time, treading, as it were, upon a carpet which they weave with whatever colors and texture they wish, but they are ever rolling this carpet up behind them and carrying it with them. Thus all of the past is preserved, though not indeed all as self-conscious memories. It is this whole past which, "gnawing into the future, swelling as it advances," Bergson calls duration. The biologic law of recapitulation takes cognizance of a part of this memory.

Thus instead of a finalistic or a mechanistic universe with its course known or foreseeable, Bergson postulates one creating itself endlessly along an indeterminable course, constantly enlarging with the volume of its past experiences.

THE ABILITIES OF AN "EDUCATED" HORSE

By Professor M. V. O'SHEA
THE UNIVERSITY OF WISCONSIN

DURING the last few years a number of "educated" horses have been prominently before the public, alike in this country and in the old world, and they have received enthusiastic praise from all sorts of people. Doubtless some readers of this article saw and admired Blondine, who exhibited his "marvelous" powers continuously during the Pan-American Exposition at Buffalo. Many distinguished people paid him a visit; and observing his performances, they went away to tell astounding tales of his intellectual acumen. The testimonies of men eminent in politics, in war, in business, and in the professions were daily published at the door of Blondine's pavilion; and the writer remembers reading the hearty commendations of this "educated" horse by President McKinley, Admiral Schley, and a long list of persons celebrated in various walks of life. The press of the country described the readiness and accuracy with which Blondine could add, subtract, multiply and divide large numbers; how he would interpret commands given to him, such as to take a handkerchief to a particular lady in a company; how he could spell words given him by members of his audience; how he could read simple sentences; and how he could perform other mental feats which we have been accustomed to think are impossible except for an intelligent human being.

Leaving aside the "educated" horses of other days and of other countries, it is the intention here to describe the intelligence of King Pharaoh, which has probably attracted more attention than any other horse of recent times. He has appeared before notable people and vast audiences in every section of this country. He has received unqualified praise for his abilities from newspaper and magazine writers, and from such persons as Ella Wheeler Wilcox, Governor Eberhardt, of Minnesota, and others of like distinction. His trainer, Dr. Boyd, of Columbia, South Carolina, claims that we have at last an animal with genuine human intelligence, as shown in his interpretation of oral and written language, his mathematical calculations, his reading of human character, and similar achievements.

The writer, who had made some observations respecting Blondine's powers as revealed in his exhibitions in Buffalo, was able to make an investigation of King Pharaoh's abilities in November, 1911. An educational convention was in session in Miles City, Montana. King Pharaoh with his trainer and retinue of attendants happened to be

passing through to the Pacific coast at the time. The train was halted at Miles City, and Dr. Boyd was asked whether he would permit the writer to make a test of King Pharaoh's reputed human intelligence, and he readily consented to this. It was stipulated that the trainer should first exhibit the horse in the presence of a body of twenty-five observers, these to be chosen mainly from the educators in attendance at the convention, after which the writer would take control of King Pharoah, and his trainer and care-takers should leave the building, so that they could not influence the horse in any way during his performances. These conditions were agreed to by Dr. Boyd.

King Pharaoh is a small pinto stallion. He has an unusually large head for his size. The trainer called special attention to this trait before beginning his performance with the horse. He also dwelt upon the remarkable success which King Pharaoh had had in all of his exhibitions. He mentioned the people of prominence who had "studied" him, and who had commended him, putting special emphasis upon the testimony of Ella Wheeler Wilcox and Governor Eberhardt. Whether the trainer intended it or not, it was apparent that his remarks predisposed the observers in the horse's favor. One could see that they were much interested in King Pharaoh's large head, which indicated, of course, in accord with popular belief, that he *must* be intelligent. "Large head = superior intelligence" is the simple logic of the uncritical observer; and such a person will be partially convinced before he sees the horse in action at all. Then when great men, no matter in what department they may have achieved distinction, testify in favor of anything, the majority of people no longer maintain a genuinely critical attitude toward it. This is the result which the trainer must have known would issue from his remarks, though he may not have made them for this explicit purpose.

It should be stated at this point that the trainer had carefully arranged the setting of the stage before King was brought in. He had placed a blackboard on an easel; and at four or five yards to the left there was a rack ten feet long on which could be placed in upright position ten letters or ten numbers printed on blocks that could be easily knocked down. The letters and figures were printed on both sides of the blocks, so that the horse and the trainer could see them, and the audience could also observe them. Throughout the exhibition the trainer stood between the blackboard and the rack so that the horse would always be in front of him, and he could see what was taking place.

For the first experiment, the writer put on the blackboard the following figures:

8 5 7 6
6 3 9 4

and said to the horse: "King, add these figures." The trainer then said: "King, do as the gentleman bids you. Go to the rack and show what is the sum of the first two figures. Go along and do it quickly." Then turning to the audience he remarked: "King is mischievous to-day, perhaps because it is so cool, and he may not do just as he should unless I compel him to. Usually I never have to take a switch to him, but sometimes when he is too mischievous, I have to correct him, and urge him to attend to his business." It was interesting to note the effect of this statement upon the observers. It put them at once into sympathy with the horse, and predisposed them to explain King's lack of responsiveness and his mistakes to his "mischief," and not to his inability to understand what was wanted of him. The remarks served effectively to divert many of the observers from studying the commands and actions of the trainer as possibly affording a clue to the reactions of the horse. They just naturally concluded that so much talk by the trainer was necessary in order to control the horse's "mischief," and it did not occur to them that verbal clues were mixed in with the commands.

Meanwhile the horse was standing at the rack without indicating any interest in the proceedings. He was not "studying" the figures on the board. He did not appear to understand what Dr. Boyd was saying about him. At least it was impossible for the writer, who was carefully noting King's reactions at short range, to detect any recognition on King's part of the trainer's remarks or commands, though it was claimed he understood every word. Turning to the horse again the trainer said, "King, why don't you do as the gentleman asked you? Find the first number. Come on, behave yourself, and find the first number," and he picked up a stick as if to slap him. The horse then walked over to the rack on which the number 10 had been placed near the lower end. He moved down to this number, and pushed it off. However, just as King came to the number 10, the trainer said, "Show the gentleman what the first number is." After having pushed off the right number, he pushed off the number 6 which was next to it. The trainer then said, "What is the number you carry? Find the number which you should carry." The horse moved along the rack, and while the trainer was talking to and commanding him, stamping occasionally to impress King with the necessity of "cutting out" his "mischief," he pushed off the number 1 and the number next to it. Then the trainer said, "What is the next number in this addition? Find it for the gentleman." The horse moved along the rack, and at the command, "Show the gentleman," he pushed off the number 13, and the one next to it. The trainer then had some one in the audience put the number 1 on the rack, though it could not be determined whether the horse was looking at the moment; and being commanded to show the

number which should be carried, King moved up to the rack, and apparently went directly to the right number, and pushed it off.

So he went through with the entire addition, making no mistakes, except that for most of the numbers he pushed off both the right one and the one next to it. The trainer in each case would take two or three steps toward him and say, "He knows perfectly well what is right, but he is mischievous to-day. Sometimes he does that, but very rarely." Then the trainer would call out to the horse, "King, if you do not behave yourself, I will whip you for it. Now you go and do as I command you." The effect of these remarks on the observers was evident; they were siding with the horse in all his "pranks," though he appeared to be in earnest, according to equine standards. The writer could detect no evidence of "mischief" in the horse's expression or action. But the observers showed sympathy with King, and delight in his evident intelligence. The writer, who did not participate in the demonstrations of admiration when King pushed off the numbers, was said by certain of the observers to be rather cold and blasé in regard to "educated" horses. One newspaper reporter who was in the audience told the writer later that he thought King would have done much better than he actually did do, if he (the writer) had not been eyeing him so coldly and unsympathetically. "I couldn't have done so well myself under such conditions," said the reporter.

The writer next wrote on the board the figures

$$\begin{array}{r} 7\ 5\ 9\ 2 \\ 5\ 1\ 3\ 8 \\ \hline \end{array}$$

and said to the horse, "King, subtract." The trainer then called to him to perform the process, using, so far as one could follow him, substantially such language as he did during the addition process. The horse in this experiment always pushed off the right number, but he also pushed off one or two other numbers in each instance. He would stop in the vicinity of the right number, while his trainer was talking to him, but apparently he could not discriminate between the correct one and those on either side of it. The trainer kept telling the audience that King knew perfectly well what was right, but he was "out of sorts to-day." So far as one could tell, the horse was utterly indifferent to his repeated verbal chastisements, even though, according to the trainer, he comprehended everything said to him and about him.

Next, the writer put on the board a problem in division, and one in multiplication, and the horse solved each problem in the way in which he did the first two; but in most of his attempts he pushed off more than one number, which the trainer uniformly ascribed to the cold weather, or to some similar cause, and not to lack of intelligence. His most remarkable arithmetical work, judging from the expressions of the audi-

ence, was his correct solution, in the same sense that his other solutions were correct, of the problem,—"If I must pay 35 cents for one dozen oranges, how much must I pay for 224 dozens?" King "solved" this "in his mind," which is more than the average high-school graduate can do. Also, he apparently carried the solutions of all the other problems "in his mind" after "studying" them once, which would be regarded as "some" feat for a mathematician even.

Stopping a moment for comments, it may be noted first that the trainer while commanding the horse saw the numbers on the rack, and that the horse passed *along* the rack, instead of walking up straight to a number. It was impossible to keep tab on all of the trainer's talk so as to determine whether he always used a given word or phrase when the horse was opposite a particular number; but some observers in the audience believed that this was true, and that the phrase he used was "Show the gentleman." It was thought by some members of the audience that the trainer always stamped his foot when the horse was to move back on the rack in order to find the right number. The writer, who remained at the blackboard while the horse was "studying" the figures, noted that he did not appear to concentrate upon them at all. The trainer would say to him as the numbers were being written, "Now, King, study these numbers, so that you can do your work quickly." The horse on at least two occasions nibbled at the writer's fingers while the numbers were being written. Once he looked out of the window; and from the focus of his eyes, which were specially observed, it appeared impossible for him to be attending to the numbers which had been written. If a child had been doing this work he would have shown in his bodily adjustments that he was concentrating upon the situation before him, but it was just the other way with King. The trainer would tell him to figure a problem all out before he went to the rack, so that he could do his work fast; and assuming that he did this, it indicated a higher degree of numerical imagery and retentiveness than the majority of human beings possess.

After the arithmetical tests, the writer introduced King to three of the observers situated in different parts of the room. Then five ribbons of different colors were put on the rack, after which the writer said to the horse,—"King, take the orange ribbon to Miss W." The trainer followed with, "King, do as the gentleman bids you. Find the orange color." The trainer was constantly talking to King, and stamping to make him obedient, and the horse soon picked out the orange ribbon and apparently went directly with it to Miss W., throwing it at her. The writer next said, "King, find the blue ribbon and take it to Mr. X." Again the trainer talked to the horse while he was performing the task, with the result that he found the blue ribbon, and took it to Mr. X. Miss W. threw her ribbon onto the floor, and the trainer said, "King,

pick up the orange ribbon and take it to Dr. O." The horse picked up the ribbon, turned around, and did exactly as he was commanded; and in this case, neither the writer nor the observers could detect any cue word or signal which was used to guide the horse. It should be said that all the observers were much impressed with the directness with which the horse appeared to go to the individual whose name was mentioned in any of these tests, though when King was being introduced to a person he did not seem to pay any attention to him. A human being would *look* at any one to whom he was being introduced, so that in the future he could recognize him through having focalized some of his characteristics; but King's eyes never once focused on the person to whom he was being presented. During the ceremonies of introduction, King might be sniffing at the writer's hand, or nibbling at his coat, which would cause the trainer to exclaim,—"King, why don't you behave yourself? I will have to whip you." But still when the test came King seemed to most of the observers to have recognized each individual to whom he was introduced, and to have remembered his name.

Next the writer asked King to spell the word "horse." The trainer took him in hand, talking to him and stamping; and the horse went along the rack and, as with the figures, pushed off in order the letters h-o-r-s-e, pushing off also letters next to the correct ones in each case. Several other words were given him, all of which he "spelled" under the guidance of his trainer. Lastly the writer printed on the blackboard the words, "Take my gloves, and give them to Miss W." The horse apparently searched around the body of the writer, but could not locate the gloves. The trainer gave the audience the impression that King was trying to find them; but while they could be seen extending out of the pocket, yet the horse did not take them. The effect created on the audience was that the horse was actually hunting for the gloves. It was noticed that as he was sniffing up and down the body, the trainer was repeating, "Do what the gentleman has asked you to do." It should be noted further that the writer stood directly before the horse, and it would be a simple matter for him to associate such a word as "gentleman" with taking something from his person. It is a frequent test for exhibitors with horses to have them take something, usually the hat from a man's head, and give it to some one in the audience.

These experiments having been concluded, the trainer and his assistants were asked to leave the building, and the horse was turned over to the writer. Before leaving, the trainer said, "The horse is very mischievous to-day, and you will have to look out for him." This had the desired effect, or at least it caused many of the observers to seek places of safety, which put them in a non-critical attitude toward the experiment. In this connection it should be mentioned that the trainer gave the writer before he took charge of King, and apparently in an incidental manner, a newspaper article which ran as follows:

"King Pharaoh," an "educated horse" who made his initial bow at Wonderland Park yesterday, vindicated his honor at the close of one of the performances of the day. There was a "doubting Thomas" in the audience who thought the horse must have been given signals of some sort to perform the mathematical and other wonders which were revealed during the performance.

The man of inquiring and suspicious nature was told by Dr. J. M. Boyd, the owner and trainer of the horse, that after the audience had left he could remain and see for himself in the absence of the horse's trainer. The "doubting Thomas" was left alone with "King Pharaoh." Shortly the man made his exit with much expedition, with the horse a close second. The animal, the man said, had obeyed several commands but seemed to become offended and "went" for him, as if knowing he was confronted by a doubter.

It seemed apparent that the object of this was to impress the writer with the desirability of his not being skeptical about King Pharaoh's abilities, or the horse might attack him and do him harm.

After the trainer and his assistants had left the hall, the writer repeated every one of the experiments which had been performed by King when his trainer was present. It may be stated in brief that he failed to perform a single test satisfactorily. When told to go to the blackboard, without any gesture or sign other than the mere words of the command, he did not respond. He could not react even to the word "blackboard." But when urged with the uplifted hand in the act of striking, and guided in the right direction, he would go and "study" the numbers. But when invited to go to the rack and perform the solution, he seemingly had no idea of what was said to him. But when urged and threatened, he would pass along the rack without knocking off any number. It was impossible to get him to remove a number by telling him simply to find the correct one. It was the same in regard to the spelling. In some cases when he was commanded in a threatening voice and manner to find numbers, he would paw, indicating that he seemed to think the command was to count. The only reaction that could be got from him was to stand before the blackboard, walk along the rack when urged and threatened with a stick, but without any disposition to solve problems, and paw when a command such as "Go and find Miss W." was continually repeated in an increasingly austere voice. It was evident that the horse had no imagery whatever for the words "Miss W.," and no notion of what was wanted of him.

The trainer, who after a considerable period had come to the building to find out the progress of events, and who stood on the sidelines while the writer was trying the horse out on some of his feats, finally could not endure it any longer, and came into the ring, saying to the audience, "Once in a while King will come across a man for whom he will do nothing; but he will readily do it for most people." This remark had the desired effect. Some persons in the audience were led to think that the writer was not in sympathetic accord with the horse, and

so could not induce him to perform his usual tasks. At once the writer called upon Professor Cooley, an expert on horses, who was in the audience, and who had seen the performance from the start, to take charge of the horse, which he did, with exactly the same result as the writer had. Next the principal of the high school in Miles City, who could not be accused of any skepticism regarding the horse's ability, or any want of sympathy for him, was asked to put King through his paces, but he could not get a single intelligent reaction from him. It ought to be added that the writer was simply neutral in his attitude toward the horse throughout the trainer's performances; he did not praise or censure; he simply took notes on each event, which impressed both the trainer and some of the observers as denoting a too critical and unsentimental relation.

It was to be expected that the trainer of King would explain his disappointing behavior as due to the paralyzing influence of strange personalities, and indisposition of some sort, for he had "never acted that way before." So another experiment was determined upon, and it was agreed that Dr. Boyd should handle the horse himself next time, and the writer would simply tell him what tests should be made. Now, it was mentioned above that in the language and arithmetic tests, the trainer as well as the audience saw the letters and figures, which made it impossible to eliminate the trainer's influence in guiding his horse, even though he might be unconscious of it. In order to try out this point it was decided, and it was thought without the trainer's knowledge, to prepare new blocks with letters and figures only on one side, and to arrange them on the rack so that the trainer could not see them while directing King, but so that the horse and the observers could see them. It was also decided to blindfold the trainer while the horse was being tested on his ability to discriminate colors, and to select special ones to give to persons to whom he had been introduced. Strangely enough, just before the tests were to be made the trainer declared that King had suddenly been taken sick, and could not be tested, though "nothing like it had ever happened to him before." To clear up the situtation, which looked very bad, Dr. Boyd promised to bring King to Madison, Wisconsin, for further experiments before January 15, 1912; but from that day to this (October 1, 1912) it has been impossible to get any response from him, though King is still amazing people with his "human intelligence."

Any one familiar with horses knows that they are capable of keen responses of a particular kind. They can very acutely distinguish tones of voice in respect to their denoting gentleness, or harshness, or weakness, or sternness in their possessors. Dogs have the same sort of keenness. Very young children, before they understand a single word as a symbol of meaning, can discriminate a number of shades in vocal qual-

ity. A horse can learn the significance of certain words which denote simple, definite reactions, as "gee," "haw," "get up," "whoa," and the like. He can be taught to respond in special cases to a considerable range of visual and auditory signs or cues, as may be observed in any circus. He can discriminate strangers from his caretakers, alike by smell and by sight, and also by the "feel" of the rein in driving him. The dominant emotion of the horse is fear, and he is keen in noting the characteristics of persons or places or objects which have been associated in his experience with pain or terror. He is extremely cautious, which keeps him ever on the alert, with the result that he will respond to simple stimuli in the form of "lessons" much more readily than the cow or the sheep, for instance. King is undoubtedly an average horse in this respect. As a result of repeated "lessons," he has associated a few visual and auditory signs with definite responses, and he has probably connected particular reactions with specific words, as "gentleman," or "show the gentleman" which is, of course, but one word to him, denoting a specific reaction, just as "whoa" does. Unquestionably much of his performance depends upon the peculiar vocal and bodily mannerisms of his trainer. When these are removed, King is at sea, hopelessly befogged when he is requested to do anything.

Those who exploit the intelligence of the horse, and other animals as well, usually try to show that they possess the traits of the human mind, in that they can understand sentences in ordinary speech, can read and spell and calculate numerically, can learn the names of people and discriminate their character, can interpret facial expression, and so on. Now, all these acts and processes demand a synthesis of particular experiences which it is safe to say the equine brain is incapable of under any kind or degree of education. If a horse could do these things, it would cease to be a horse. The reason a horse is a horse psychically is because it is limited to certain types of intellectual synthesis and affective reaction, all of which have been determined by its ancestral history. It would be just as sensible to say that a man could be educated to follow the trail of a fox from the scent of its track, as to say that a horse, or any other animal, can be trained to read or calculate sums or discern a skeptic in an audience. This is not reflecting in any way upon the intelligence of the horse; it is simply discriminating between the characteristic types of equine and of human intelligence. But if it were not financially profitable for some persons to possess horses with "human intelligence," we probably should never be called upon to wonder about them.

THE ADVANCEMENT OF PSYCHOLOGICAL MEDICINE

By FREDERIC LYMAN WELLS, Ph.D.
McLEAN HOSPITAL, WAVERLEY, MASS.

TEACHING and research are the coordinate ways upon which any body of knowledge advances. Though we are apt to think first of the former, the latter is indeed the more basic, since before we can talk of teaching we must acquire something to teach; as, to a large extent, it is still the task of psychological medicine to do. It is neither a difficult nor an especially effective matter to urge in generalities the desirability of medical training in psychology in the hundred trite phrases that are current to every one; the abstractly favorable judgment is now of little meaning except as the basis of constructive ideas. We can best decide the place of psychology in medical education in examining what is the best that psychology has to give it. This question could indeed be dealt with more simply if there were greater unanimity of opinion as to what this best may be; for, as the recent addresses at Washington plainly showed, divergent opinions still reflect the different angles from which the subject is approached. The discourse of the medical man is one of problems, of the psychologist, one of methods; which under present conditions could scarcely be otherwise. The difficulty is that the methods of normal psychology and the problems of pathological psychology do not fit. One could well read this in and between the lines of Franz's remarks,[1] deprecating certain inadequacies in the methods of pathological psychology, as well as the aloofness from practical issues on the psychological side. The doubtful attitude of the psychiatrist towards the psychological *Problemstellung* is of long standing. "They ask for a psychology . . . applied toward a solution of their own problems, one which is aimed at practical ends. It has been assumed that psychology as it is being taught and investigated deals with matters of no concern, or of too abstract a nature for practise"; which assumption indeed has some measure of truth.[2] Psychologists may not be scientifically at fault for this failure of application, but the medical justice of demanding it can scarcely be gainsaid, and such expressions are fair warning that in our natural wish to extend the scope and influence of psychological science, we do not lose sight of the fact that if psychology is to be successfully taught to medical students, it must afford them something they can use. The test of concrete experience is one that psychology has never been seriously called upon

[1] *Journ. Am. Med. Assoc.*, March 30, 1912, 909–911.

[2] Cf. Hollingworth, *Psych. Bull.*, May 15, 1912, 204–206.

to face, in the sense that other natural sciences have been. I am fully mindful of Professor Titchener's[3] cogent *apologia* for the failure of the contemporary psychology to "hold its men," who tended either to leave it for more frankly speculative departments of thought, or sought the concreter fields of education, or physiology and therapeutics. But the fact seems to be that psychology has not been over-forward in seeking the test of concrete experience.

A somewhat definite program for the medical course in psychology has been discussed by Watson.[4] It seems, not unnaturally, determined more by the place of the methods in experimental psychology than by direct consideration of their applications to the study of psychopathological conditions. From this standpoint, one might in minor detail suggest some modification of Professor Watson's plan; thus in any work on sight, campimetry should probably occupy an equal place with color vision. The skin and kinesthetic sensations have a psychopathological importance quite equal to that of hearing. Watson's plan is for a systematic experimental course; I must confess that what seem the most fitting topics do not coordinate themselves so readily in my mind, and my own tendency would be to make such a course less one in experimental psychology than in psychological experiments. The content of the laboratory course may indeed change with the progress of the science, in accordance with the principle that properly governs it; but as we are not trying to make psychologists, but medical men, we must subordinate the desideratum of the academic system to a series of those experiments and methods most likely to be made use of in actual medical practise. It is evident that in the determination of the proper subject matter of such a course, there enters not only the available stock-in-trade, so to speak, of experimental psychology, but also the consideration of those particular clinical exigencies in which they are likely to be of service. Only such experiments and methods should form a part of such a course for which definite value in special situations can be indicated; and the understanding of the application is on a level of importance equal with that of the experiment itself. The application of experimental methods will, of course, be practically confined to the study of individual cases, and the procedure which should be followed in the laboratory is thus an intensive study of each experimental method with individual subjects; group experimentation or methods which involve it are out of place in such a course.[5] In an enumeration of the experimental methods which would seem, from the writer's particular experience, to best deserve place, would be included the study of the

[3] *Am. J. Psych.*, XXI., 1910, 406–407.

[4] *Journ. Am. Med. Assoc.*, March 30, 1912, 916–918.

[5] Cf. Kraepelin, "Ueber Ermüdungsmessungen," *Arch. f. d. Ges. Psychol.*, I., 1903, 28.

free association experiment, the technique of the "psychogalvanic" reflex, or some allied method, the properties of the work-curve and a few of the less equivocal methods for determining it, and the better developed forms of memory experimentation. Nor should I question the inclusion of the Binet-Simon tests, though without personal experience with them. It would lead too far afield to explain just why these particular experimental methods have been spoken of and not others, but suffice it to express every assurance that they are among the methods most helpful to the better understanding of those cases with which psychiatric clinics are replete. It is true that such division would form practically separate units in the course, and they could be taken up in any desirable order, save that, *e. g.*, certain phases of the association experiment and the "psychogalvanic" reflex are best considered together. Whether the content of a laboratory course were as above or something totally different, it must be governed essentially by its medical usefulness, and those features included which best justify themselves in this light. How much time can be given, and when, depends of course on administrative factors; all the time that Watson suggests could be profitably used, and it should be so ordered as to be convenient for those who take up the special work given in mental diseases.

Such, in principle, is the writer's conception of a laboratory course likely to be of most value to students of medicine, nor would it be claimed that its subject matter could be effectively dealt with under other than laboratory conditions. There yet remains that considerable body of psychological problems whose concern with medicine is not less immediate than those above, but whose relation to experimental, or indeed in any way objective, methods, is at present very indefinite. They are essentially problems of psychogenesis—the development of the various mental reactions and tendencies of which individual character and temperament are built up. It is readily discernible that a growing emphasis is laid in psychopathology upon the determining if not conditioning rôle of psychogenic factors in a variety of conditions, ranging from hysteria to the manic-depressive group; though the scientific development of methods, or their application to the study of normal mental reaction types, has been largely conspicuous in absence.

It is this phase of the situation that looms largest in Meyer's vision,[6] with especial regard to its problems. The point of view goes back to some basal concepts of "mental reaction"[7] and the remarks represented a none the less forceful, if indirect, criticism of the conventional *Fragestellung* in its relation to the problems on the pathological side. While at various times psychological writers have deprecated the tendencies inherent, from a scientific standpoint, in many doctrines associ-

[6] *Journ. Am. Med. Assoc.*, March 30, 1912, 911–914.

[7] Most simply outlined in the *Psychological Clinic*, June, 1908, 89–101.

ated with the name of psychoanalysis, it would be difficult to deny that the responsibility for psychoanalysis rests to some extent with the psychologists ourselves. The neurologist found himself confronted with certain problems psychological in their nature, with which the academic psychology had largely thought best not to concern itself. It is true that we have an "individual" psychology; one of the differences in simple reaction time, in color vision, or in memory for nonsense syllables, various elementary traits among which it has been difficult to establish relationships or other than superficial interpretation. From a medical standpoint it is better to give up this *Problemstellung* of individual differences in functions, for one, so to speak, of individual differences in individuals. The medical requirement is rather for a psychology that shall seek the correlation of objective methods for studying the personality with the mental reactions of that personality in the greater laboratory of mundane experience. The key-word to what medical psychology should be, and what academic psychology has not been, is, in fact, "*personality.*" To our conventional chapter-headings of imagination, will, habit, experience and the like, let us mentally add the words *as they affect the personality,* if we wish to reach the standpoint of the greatest help in the medical relation. We shall study the mental evolution of the individual, rather than the genetic psychology of different mental faculties. Our psychology will be one of conduct, reactions, adjustments. As such we shall pay greater heed to feeling as a disturber of these adjustments. We shall start from the standpoint of the "mind as an adaptive mechanism";[8] the personality as a sum of various tendencies in mental adaption or reaction-type. We shall study the various mental means through which different personalities react upon, or adjust themselves to, the vital situations they meet. We shall learn how some personalities react in ways that involve mental good, others in ways that involve mental harm, and we shall inquire into the modifiability of these reaction types, with the view to their possible amelioration.

Though having a somewhat different outlook upon the matter, and expressing it in different terms, it appears that the things which Prince[9] finds to criticize in the pathological relations of the academic psychology are essentially the same.

> The problems with which normal psychology has chosen to deal are exceedingly interesting from the point of view of the higher culture, but they scarcely touch the vital questions which the disturbed, distressed human organism presents to the physician. . . .If normal psychology is to become an applied science and in particular to become of help to medicine, . . . it must occupy itself more than it has done with problems of dynamics, of mechanism, of function.

[8] Cf. a lucid but uneven article by White, "The Theory of the 'Complex,'" *Interstate Med. Journ.*, XVI., 1909, No. 14. Also in "Mental Mechanisms," Ch. 4, pp. 48–70.

[9] *Journ. Am. Med. Assoc.*, March 30, 1912, 918–921.

He goes further, however, in formulating a definite scheme of instruction. This is governed in certain details by its author's special psychology; some rearrangement of headings, if not also some alterations of terminology, might well prove desirable. Yet it is quite evident that in a number of the titles we have at least an enumeration, in greater detail, of the phases which a course along the lines above indicated would take up.

When Dr. Prince was reading this summary in Washington, I turned to some one sitting next to me and rather lightly remarked that this was all very well, but Prince was the only man who could give such a course, my neighbor promptly assuring me that I was altogether mistaken, that he knew many persons who could give such a course. It was not meant, of course, that there was no one who could talk about these subjects for the number of hours the course would specify. But we can not consistently reproach psychology for our lack of knowledge in these matters, and at the same time propose their immediate fitness as a teaching subject. As a matter of fact we have very little systematic information about the majority of the topics presented in Prince's summary. It is most likely to increase if the student be brought to observe and study in his cases in these terms, but this side of the course could to-day no more than reflect the subjective reactions of certain original and more or less critical intellects upon the most adequate clinical experience.

The interest and import of these questions most thoughtful persons will admit, though any psychological critic would probably be quick to ask how such matters are to be in any part submitted to objective, not to say experimental, inquiry. Not with the color-wheel probably, or through the tonvariator, or the sound-hammer. Could the question now be satisfactorily answered, the proper psychology for medical schools would not be long under discussion. We are not in a position to say, however, that no progress towards a solution is possible. Our experimental inquiries have not been directed along lines that would develop such methods. We must also know with greater exactitude the questions our experimental methods are to be put to answer, and shall need to experiment with our experiments a good deal. There is to-day only one experimental method whose direct value in the dynamic psychology seems comparatively assured; this is the ordinary "free" association experiment, especially evaluated.[10] There are also some possible adaptations of the method of "measurement by relative position"[11] as well

[10] Cf. the "Diagnostische Assoziations studien" of Jung; Kent and Rosanoff, "A Study of Association in Insanity," *Am. Jr. Ins.*, LXVII., 1910, 37–96, 317–390.

[11] Cf. the early work of Sumner and the more recent studies of Hollingworth and of Strong; also, in pathological reference, G. G. Fernald, *Am. Jr. Ins.*, LXVIII., 1912, 545–547.

as other quite specialized tests, that hold out promises of value in these directions.

It will be appreciated that a dynamic psychology has no exclusive relation to the pathological, but rather seeks the recasting of psychological problems into a form more applicable to the uses not only of pathological psychology, but of normal psychology and society in general. It is in no way specificially referred to pathological material. Because psychiatry has to deal, on the mental side, with personality, it desires a psychology of personality. The study of normal personality, as such, has its obvious and necessary relation to the pathological. The university is in quite as favorable position to make essential contribution to a psychology of personality as is the hospital or clinic. Research in this direction encounters certain difficulties that are avoided in the customary lines of psychological investigation, but this is so by very virtue of its having personal applicability, its bearing upon more intimate and vital issues.

To adequately cover the teaching field of psychological medicine one should therefore, on the one hand, be conversant with and able to judge of the methods of experimental psychology in reference to their application to the analysis and interpretation of symptoms; and, on the other hand, able to recognize and elucidate the more general questions now stated dynamically. First-hand acquaintance with psychiatric conditions and problems is everywhere implicit, which involves the close and continual association with clinical material that is also necessary for research. Here then the problem of research merges with the problem of teaching, and we shall consider some phases of the subject also from this standpoint. It is proposed to discuss in this connection not the further special topics of investigation,[12] but the practical conditions under which such research takes place, and the most effective means of furthering it.

The essential clinical material of psychopathology is derived from various sources, approachable from different angles. According to social stratum, the neuroses and various border-line and neurological conditions are most seen either in the private practise of the specialist, or in the appropriate departments of the general hospitals; the psychoses, as the term is generally understood, in the state or private hospitals devoted to their care and treatment. Special institutions, as a rule, care for the graver congenitally defective (feeble-minded) while in some instances it has been found advisable to provide special institutions for the management of such conditions as epilepsy and alcoholism. Much the greatest amount of material, and in its most accessible form, exists therefore in the institutions; though it does not so greatly

[12] Some of which the writer has dealt with elsewhere; cf. "The Experimental Method in Psychopathology," *N. Y. State Hospitals Bulletin*, December, 1910.

surpass in psychological interest the smaller group of neurotic conditions that do not regularly come under institutional care.

It is not now easy to say how this latter group of cases will to any extent be brought under the observation of the psychologist. Except in isolated instances, the material of private practise may be systematically observed only by the physician who treats it. For our psychological understanding of these cases, we shall presumably remain dependent upon such studies as the specially interested physician is able to make in the course of his practise. These researches should improve in number, if not also in quality, as medical students acquire more knowledge of psychopathological problems, and of the means by which to approach them. The case is more favorable with that part of this material than is seen in general hospitals, or in small private institutions, but the obvious economic difficulty of providing for the systematic psychological study of this material is one which it has not yet been attempted to meet. If these conditions are thus less accessible as a group, it is partly compensated for by their greater accessibility as individuals, owing to the generally better preservation of the intellect and cooperative faculties, so far as these enter. In the comparative study of the neuroses and psychoses, these factors to some extent balance each other.

The most practical means to further the accessibility of psychopathological material for psychological research, has been through the establishment of research positions in the institutions whose facilities are adequate to them. The past decade has witnessed the inception of a considerable amount of this work, under various state and private auspices. The conspicuous success of Franz at Washington and of Goddard at Vineland may be mentioned. These positions have been regularly filled by persons of the university training in psychology, who are expected to devote their time to original investigation. Whatever the special character of the material investigated, the main responsibility for psychopathological investigation will rest—and perhaps it may be added that it ought to rest—with the men in these positions, relieved of the perpetual penalty of therapeutic promise. As the success of these positions depends upon the men whom they will draw, and this in turn upon the opportunities they offer, it may be well to briefly analyze from both standpoints the external conditions under which this work is done.

Institutions that make scientific appointments are presumably ready to devote themselves in some measure to work of a purely research character, the immediate practical realization of whose benefits is likely to be a matter of more than ordinary good fortune. The creation of such positions therefore implies in the administration a fair degree of sympathy with scientific motives. Institutions inadequate to this de-

mand are scarcely suited for such positions, nor are good men for the work likely to be drawn to them. The salaries vary somewhat from place to place, and according as the incumbent lives within the institution or out of it; but a fair average compensation for work of this nature has been $1,200 a year plus maintenance. The teaching positions which psychologists ordinarily enter do not, of course, provide training of any particular technical value for these research activities; in some cases they might even lessen fitness for research. As Wallin[13] put it, the only adequate training in this respect is an apprenticeship with one of the experts in the field, which is very rare at present. On the other hand, much might be said for the value of direct experience in allied fields, and their additional contacts with the broader problems of social psychology. In Titchener's ever-apt phraseology "the best work will always be done by the best men," who, with a mature outlook upon the psychological situation and its problems, enter the pathological field because of exceptional interest, or are selected at the outset of their careers through evidence of fitness and promise in these special questions of research. With the above reservation, the candidate is the fitter for the position the less the time since his Ph.D., and the positions should be made attractive to those at the outset of the psychological career.

If qualified men are to be drawn to these positions, they must be given a standing in keeping with the class of work expected of them. It should be commensurate with that accorded to the pathologist, who forms an integral part of the institution staff. Discrimination will simply exclude the more competent men. It is doubtful if the scale of salaries needs to be altered greatly. The additional cost of carrying on such work would include not less than $150 for annual library expenses, the remainder being dependent on the sort of work done, and the special equipment it requires. Many fruitful lines of inquiry require but little apparatus beyond stationery; some important problems, *e. g.*, those concerned with the expressive movements, require elaborate and somewhat costly installations. Administrative direction of the precise subjects of research is not usually advisable, however, since it can seldom be guided by an adequate knowledge of the limitations of methods. In no case should the attempt be made to equip a general laboratory, but only to provide such equipment as is necessary for the investigations in hand. At some time in most investigations a certain amount of clerical assistance is an all but absolute requirement, and no holder of such a position should be expected to do his work properly without it. The greatest possible latitude should exist in regard to questions of printing; if an investigator is not to be trusted to publish when, where and what he thinks best, something is wrong with him or his position.

[13] *Journ. Educ. Psychol.*, April, 1911, 208.

As the worker in an institution laboratory does not have the same opportunity to place his work before *Fachgenossen* as is the case with his university colleagues, the institution may well accord some facility in the distribution of offprints.

From the standpoint of the young Ph.D., these research positions are economically quite superior to anything to be expected of the earlier years of a teaching career. As maintenance is provided, a very large part of the salary can, if desired, be saved; the conditions of living vary with the character of the institution, but may bring the actual value of a $1,200 position well towards $2,000. Vacations are short, compared with academic ones, but this may be quite compensated for by the absence of routine obligations and various other agreeable features of institution surroundings. The tremendous advantage, to him who is able to use it, lies in the freedom for original research; the possible disadvantages are the lack of library facilities, and the intellectual danger of isolation from colleagues. Absolved from routine activity, deprived of the immediate competitive and critical presence of others in the same field of work, the lack of energy and devotion means mental dry rot. However, being not only free, but expected to devote one's entire time to original research, one can obviously be more productive than his equally capable fellow-worker whose time is swamped by the routine activities of teaching; and, so far as personal advancement is based on the character of work done, the advantage seems to lie distinctly with the research position as against the teaching one. Still neither standing nor salary in these positions equals the professorial grade in the important universities, which is, practically speaking, the material end to which those following the career of psychologist now look forward; and once having abandoned the teaching side of the profession one is not likely to reenter it at a higher level, save upon evidence of altogether distinguished merit, probably more than would be necessary should the candidate follow the routine of academic promotion. For the greatest abilities these positions should then offer the greatest rewards; to mediocrity they spell destruction.

The cause of research in psychological medicine will prosper the better, the longer its special class of investigators can be held to their work. At present, the best men may not remain in it permanently, but be taken away at a time when their growing experience makes them increasingly valuable in it. It can not, of course, be questioned that this same experience, with the facilities of the position, places one in a peculiarly advantageous situation as regards teaching the subject, which it might be advisable also to do, in so far as it were possible without hampering research. University association with clinical research further offsets the possible difficulties of inadequate libraries and isolation from colleagues. An additional advantage of university associa-

tion is that advanced students, academic or medical, may be brought into direct contact with research problems in psychopathology and means thus provided for the carrying on of much additional investigation. Under the present circumstances the clinical psychologist might often occupy his time very effectively with the combination of research and the training of others in its methods and problems; while from a practical standpoint it also tends to retain him longer in the work to do so.

The optimum of teaching in medical psychology involves, therefore, a unification of instruction and research. It deals, on the one hand, with the clinically useful procedures of experiment; on the other, with the broader problems of personality and psychogenesis. Its contemporary sources are, on the one hand, the university laboratory, on the other, hospital clinic, and it is best served by the experience of both. Throughout, it has been apparent that the subject matter of psychological medicine is one of particular appeal to students specializing in mental diseases, and should for the present be elective. It would be rather unwise to now seek the required study of psychology in medical schools, as psychology is not yet in a position to make sufficiently definite contributions of general value. Only through the encouragement of research, and its direction through proper teaching, are its great and obvious deficiencies to be supplied, and the endeavor has been to indicate how psychology and medicine can best meet upon grounds of mutual helpfulness towards this end.

IMMENSE SALT CONCRETIONS

By Professor G. D. HARRIS
CORNELL UNIVERSITY

Crystalline salt masses may be a mile in diameter! Where are they? How were they formed? Who said so? Interrogations like these are sure to be forthcoming from layman, chemist and geologist alike whenever such startling assertions are made.

Salt is a common substance. Its occurrence in the waters of the ocean, as well as those of land-locked, mouthless seas is a matter of common knowledge. Interesting articles too, have been written regarding the immense layers of rock salt within the earth's crust. They have told of the hundreds of years required in excavating the great chambers and galleries in the Austro-Hungarian mines at Hallstadt, Ischl and Weiliczka. Such mines have been the *chose-à-voir* for travelers in this monarchy for the past two or three centuries. The Stassfurt mines have become known throughout the world for the richness of their potassium deposits. The Salt Mountain of Cordova, Spain, and the Salt Cliff at Bahadur Khel, in the Trand Indus region of India, are among the notable rock-salt occurrences.

All these salt accumulations have been explained (and perhaps properly) by supposing that they represent the residue of evaporated saline waters, waters that occurred in cut-off bays or sounds, receiving but occasionally supplies from the neighboring ocean, scarcely equaling the vapors lost by evaporation.

Of late an entirely new method of accumulation or growth of rock salt masses has been discovered. Here the salt no longer occurs in thin but wide-extended sheets, layers or strata, but in huge lumps, concretions we may say, with vertical and horizontal diameters approximately equal. These are the masses we wish here to bring to the attention of the reader. We do not have to go to Spain or India to see these marvels. They are, so to speak, right at home. They occur encysted in the sands and clays of the later geological formations along our gulf coast, from east Texas to south Alabama inclusive. Not all are immediately along the gulf border, to be sure, but the majority are but a few score miles from this line. All have doubtless a general conception of the low, grassy marsh-lands of southern Louisiana with its intricate system of tidal bayous beset here and there with dark green live oaks giving the appearance of old-time great apple trees in a great meadow, when viewed from a distant vantage ground. Doming up here and there in

these monotonous marshlands are great swells of terra-firma, one hundred or more feet in height and a mile or more in diameter. They are seen from a great distance, and strike one at once as being something out of the ordinary, surely formed by no common method of uplift, less yet by circumdenudation. Of these coastal mounds the so-called "Five Islands," lying to the east of Vermilion and Atchafalaya bays are splendid examples. Belle Isle is just to the west of the Atchafalaya River, between Morgan City and the Gulf, Côte Blanche, Grande Côte, Petite Anse and Côte Carline follow to the northwestward in the order named. The first, or Belle Isle, is famous as the fabled residence of Lafitte, the great Gulf pirate, Grande Côte and Petite Anse for their salt mines and Côte Carline for the southern home of Joe Jefferson, the actor. The drill has demonstrated the fact that these rounding hills are the surface indices of salt masses below. Down one, two or three thousand feet drills have penetrated with but little variation of matter and structure, making, as already observed, the salt masses perhaps as deep or deeper (thicker) than they are in horizontal diameter. Just off the mound one may drill two thousand feet and encounter nothing but soft clays and sand of Quaternary or "Recent" age. Below are similar materials belonging to the Miocene Tertiary; there is no salt, sometimes not even salt water. Such strangely local salt lumps naturally have troubled the philosophical geologist not a little. Some have said they must have been formed in the crater of some dying volcano, seawaters having oozed in and evaporating deposited salt for years and years in a streaming caldron. But alas for this explanation, these salt masses are not simply the residue of evaporated sea water, they are 99 per cent. chloride of sodium and without the admixture of crater débris. They are pure and solid. Again, though careful magnetic surveys have been made about them, they fail to show any of those erratic local variations sure to occur in volcanic regions. Finally there is proof positive they were never deposited in a hole or depression, but on the contrary have even *moved upward bodily through hundreds of feet of surrounding deposits!* This seems at first absolutely impossible and as certainly absurd. Nevertheless, we can demonstrate the point beyond doubt. Note that we have said that certain of these salt lumps occur some distance from the Gulf coast, up country, so to speak, where the terranes are of Tertiary and Cretaceous age and are more or less consolidated. For example, in north central Louisiana salt comes near the surface of the soil in circular areas. Surrounding these areas are rings of highly tilted Cretaceous deposits, still outside are the lower Tertiaries, 1,000 or 1,200 feet thick. Clearly then these salt punches, so to speak, have pushed themselves from amongst Cretaceous rocks right through the Lower Tertiaries, bending these strata up on all sides of the mass, to a height of 1,000 or 1,200 feet. The case then seems clear that the salt

masses have come from below and have moved upwards. This is as clearly demonstrated as the fact that the battleship *Maine* was wrecked from a force without "because the plates were bent inwards." Were the Tertiary and Quaternary beds removed from the flanks of these salt masses we should see a cylinder or perhaps more accurately a truncated cone of salt standing upon mid-Cretaceous rocks towering upwards half a mile or perhaps a mile, though the upper end of the cone might not be over ¼ mile across. Some one will say that is certainly similar to the church-spire spur that was lifted out of the crater of Mt. Pelée after its recent destructive eruption. Others will be reminded of Bogoslof Island in Alaskan waters. But here again, in endeavoring to explain the phenomenon there is no need of invoking vulcanicity. For the past ten years we have had exceptional chances to study all these interesting salt masses and are prepared to confidently affirm that the origin of both salt masses and their movements has nothing to do with volcanic action.

The true explanation of the origin, growth and movement of these salt masses seems simple when once we have a clear understanding of certain structural features of the lower Mississippi region. Observe on any geological map that Quaternary and older rocks back to the medieval or Cretaceous beds all slope Gulf-wards at a much greater angle than the surface of the ground makes with the horizontal. In other words, if water should enter a pervious Cretaceous or older bed in Arkansas and follow the same to the latitude of the Gulf border it would find itself several thousand feet below the Gulf level. Such waters would naturally become very warm as compared with water at or near the surface. They would take soluble substances in solution. If a break or point of weakness occurred in the superincumbent beds such hot waters would ascend after the manner of water in an artesian well. If the waters were saturated with salt at a high temperature they would be obliged to part with some of their saline burden as they approached the upper, cooler strata. The amount of salt held in solution by water at various temperatures, it is true, increases not greatly with increased heat; nevertheless, it is appreciable, and in the end the giving up of salt by lowering temperature would produce notable results. Again, though salt masses might tend to accumulate as just outlined at a certain place in the crust of the earth, would not pressure prevent such a growth, and even if growth takes place what would tend to push the salt up bodily say 1,000 feet or more? Here again we need none of Vulcan's aid, for we all know that when once crystallization commences each little crystal will have its growth in spite of almost any resistance. Witness the growth of ice crystals in our water pipes in zero weather. In other words, the force exerted by growing crystals is known to be at least of the same order of magnitude as the crushing

strength of the grown crystal. Therefore we are sure growing crystals of salt can lift a column of Gulf coast deposits at least 3,500 feet thick. If brine is supplied to a salt mass from below, crystallization will take place mainly on the bottom of the mass. Therefore the mass will grow from bottom up. The top will be thrust through the superincumbent beds, bending and tilting them up at high angles. Some growth would doubtless take place on the sides of the mass till it attained considerable dimensions; afterwards it would be confined to the base, for the column of rock salt would be a better conductor of heat than the surrounding clays and sands, hence the marked change of heat, hence the salt deposition would take place at the base of the salt column. The mass would therefore be of comparatively small diameter, though its depth might be great.

We see from the above considerations how salt masses might be formed and how they would by receiving their growth increments from the bottom seem to move upwards and pierce the superficial layers of the earth's crust and there be truncated by atmospheric agencies if they actually reached the surface, or how they might produce great weales on the surface in case they did not quite pierce through. Now we wish to give a few facts indicating that the process outlined above is truly that by which these salt masses were formed and pushed up. Referring again to Gulf-coast structural features, noting the location of all the salt masses known to date, we have little difficulty in satisfying ourselves that such masses are located in a rectilinear manner, row after row as we approach the Gulf border. These lines are parallel in a general way to fault lines farther up country in Arkansas and Texas. A movement along a fault line, similar to these, most readers will remember caused considerable trouble in the region of San Francisco but a few years ago. Where such lines cross (for in Louisiana there are two sets) points of weakness occur permitting the upflow of artesian waters. In several of the "mounds" these waters are saline and "hot."

Finally the source of the salt itself has been a subject of much speculation. However, it is a matter of no serious concern for us here. We know that artesian conditions occur in the general region we are discussing, we know that there are breaks or fault lines and points of weakness through which artesian flows may take place, we know that deep artesian waters are always regarded as "hot." We know that cooling saturated solutions of salt in water must be continually giving up salt; and as this crystallizes it forces aside and upwards superficial rock strata even to depths of several thousand feet. Not only do we know it has strength to do this, but, best of all, there in the Gulf region are the salt masses and there are the bent-up and folded-back rocks. Still we may be permitted perhaps to speculate re-

garding the source of the brines that have fed these growing crystalline masses. It is well understood that the thick coal-bearing rocks of west central Arkansas derived their material from the south. The Carboniferous continent extended Gulf-wards doubtless as far as the southern limits of Louisiana and perhaps considerably beyond. These old lands were eroded and swept northward into the Carboniferous seas of west Arkansas already referred to. In Permian or slightly later times this continental area was base-leveled, standing on a par with west Kansas and north Texas, receiving deposits of salt and gypsum in shallow sun-baked seas. After considerable accumulation of these saline materials the Gulf region was depressed at the south and covered by later and later deposits and the Gulf invaded the Mississippi valley to Cairo, Illinois. This was in late medieval geological times (late Cretaceous). Since then the central part of the continent has gradually raised, the Gulf border has sunk so that, through the Tertiaries and recent ages, the formations have been tilted more and more to the south till the salt-bearing Permian beds are doubtless 5,000 to 8,000 feet beneath these younger deposits. Hence in all probability the source of the artesian flow of brines that produce the salt masses under discussion.

COLLEGE OR UNIVERSITY?

By Dr. STEWART PATON
PRINCETON, N. J.

WHAT is the difference between the college and the university? There is no blinking the fact that many of the students, most of the alumni, as well as a large proportion of the members of the faculties and administrative boards, including presidents, have very nebulous views in regard to the fundamental distinction that exists between these two classes of institutions. The successful administration of a college or university depends upon the recognition of the existence of a vital principle which distinguishes the functions of one from those of the other. Many colleges during the last thirty years have assumed the title of "university," having first given a promissory note to the public expressing their intention some day to make good their claim to the title. Thinking people have already begun to express doubts as to the satisfactory fulfilment in many cases of such a promise made before the conditions and responsibilities of the trust had been fully understood by either faculties or trustees.

The time has now come for a clear understanding of the nature of the difference which distinguishes the university from the college. The evils of the *laissez-faire* policy of administration which to-day prevails in the councils of our universities have at last aroused more than one faculty and not a few trustees to a realization of the fact that while a ship at sea without chart or compass may, if the fates are propitious, be brought safely into port, the mere accomplishment of such a difficult task does not increase our sense of confidence in those responsible for providing for the safety of the voyagers. A trustee of one of our eastern universities has recently affirmed that the greatest need of these institutions is not money, but the services of men who have just and definite ideas of the essential characteristics of a university. If our higher institutions of learning are ever to keep pace with the intellectual progress of the nation (the question of actual leadership can not yet be considered), there is immediate need of a statement emphasizing the distinction existing between university and college, in order that such an institution may develop a healthy independent existence.

What is a university? There are two ways of attempting to answer this question. First there is the method usually employed of approaching the subject by indicating the lines of historical development; or we may try, and this is the object for which this paper was written, to define this institution in terms which will indicate the relations it should present to the development of human thought and

activity. So many institutions have assumed the name without justification by deeds that it is necessary to lead up to our definition by a preface of negation. The university is not, as some people believe it to be, an overgrown college with an increased number of students, a larger faculty, and greater material resources. Neither is the principle upon which it is administered one that is based upon an expression of merely local or parochial interests. Chauvinism and insularity do not thrive in the true university atmosphere. On this account, it is impossible to conceive of any university as an institution which is solely dependent upon the support of its own alumni.

In order to understand the positive attributes distinctively characteristic of a university, we must have some clear conception of what constitutes an education; inasmuch as the institution under consideration represents the acme of the entire educational system.

Education, according to the original usage of the word, is a *leading* out process, marked first by an attempt to measure the individual's capacity and then to direct his energies along lines where growth is possible. From this it is obvious that the chief aim of education is the cultivation of good mental habits and not the imparting of information. Modern educational reforms have for their object instruction in methods of work, the information incidentally supplied being of secondary importance. The older system put the chief emphasis upon the imparting of information. First one set of correctives or tonics and then another was administered to students, and if they survived the treatment they were classed with those "who had received an education." Fortunately, there are signs that the age of this form of drug-giving is rapidly passing away. A few pedagogues still have faith in cultural specifics and liberalizing studies, with virtues as well advertised and as highly extolled as any of the life-giving tonics and nostrums of the quacks, but the general public is beginning to appreciate that the original use of the word education, or intelligent effort to e-duct, not a forcible attempt to ad-duct, expresses the modern trend of our educational system. Recently the suggestion has been made that mental training is the only remedy for most of the evils connected with our present system of education.

How often the cart is put in front of the horse! How often cause is mistaken for effect! People possessing special mental qualities have predilections for certain subjects and these choices are the expression of a complex individuality largely made up of factors acquired, not by training, but by heredity. The doctrinaire often attempts to reverse the natural order and attributes the characteristics of the personality to the subjects studied. If the humanizing and cultural potency of an education depends upon the proper selection of subjects of study, what a poor showing is made by the human race after centuries of expectant treatment! How long will the old superstition that all

mental disorders, as well as all bodily ailments, can be cured by administering the proper combination of drugs continue to delude a credulous public?

Modern education starts from quite a different standpoint, first taking into account the biological or inherited trends of the individual, and then trying to estimate his latent capacity or brain-power in the expectation of giving the assistance needed to help the student in the task of self-government and self-improvement. We talk so glibly about "hereditary influences," "individual capacity," "individualism as opposed to collectivism," that, if we had a keen sense of humor the ridiculousness of a system of tutelage which attempts to treat students *en masse,* without any reference to their inherited traits and natural capacities, would strike us as farcical. This method has been described as "education by cram and emetic." In the model school or college the different subjects should not be taught as ends in themselves, but in order to train the student how to observe intelligently, concentrate his attention, repress unhealthy instincts and cultivate those qualities making for a broader, saner life. From kindergarten to the day of graduation from the university the mental training of students is dominated to so great an extent by the servile preparation for examinations that a special degree of B.E. (bachelor of examination) might be conferred on all applicants who require written evidence of having satisfactorily "passed" in order to be assured of their right to be classed as "educated persons."

An education should, as Goethe expressed it, make it possible for the individual to live his life to the fullest. Only after the idea has been clearly set forth that education and mental training should be synonymous terms are we ready to comprehend the relationship of the college to the university. Having grasped this principle, we are then in a position to realize that in the school and college every effort should be directed to the formation of good mental habits, while in the university the student should be given, under general direction, an opportunity to practise these habits, and, in addition, to develop to the fullest extent possible the spirit of intelligent curiosity.

Without the presence of universities, whose chief aim should be to cultivate the spirit of investigation and of open rebellion against conventional teaching-authority, the intellectual vigor of the entire nation is seriously impaired. Political freedom can never atone for the loss of intellectual liberty which should be faithfully guarded by the university. In a democracy there is constant danger of forgetting that the loftiest ideals of freedom are not those associated with the political life of the nation, but are indissolubly connected with the search for the truth that alone makes its possessor free. How strange that in a nation which boasts of the freedom of its political institutions so little is done by our universities to encourage and protect the agencies which

are the basis of both intellectual and individual liberty, from the paralyzing influences that follow an attempt to meet the conventional social requirements in education. Intellectual liberty often thrives best in states where political freedom is restricted.

The collegiate university is so much occupied in distributing ready-made educational suits cut upon a single pattern to applicants for academic honors, that individualism is almost completely hidden by a garb which may conceal both the iniquities of mediocrity and the virtues of genius.

The American college graduate is so accustomed to the evils of a system in which he is pulled and pushed about by "trainers" that he is constantly in danger of losing his personal identity. His patience is often exhausted by listening to sermons on the advantages of scholarship, while he prays in vain for the opportunity to learn by observing living examples. Many of the crudities in our intellectual life as a nation are directly attributable to the failure to appreciate the importance of university ideals to the community and the nation. This oversight also emphasizes our reluctance to recognize that the spirit of enquiry is a normal instinct which if repressed is followed by serious consequences such as the loss of placticity, of intellectual vigor and of the highest forms of intelligent and sympathetic interest in one's own profession. The vision of those who are fortunate enough to possess the spirit of investigation, one of the surest signs of mental health and vigor, is towards the future, while the fate of individuals and institutions which turn to look back is the same as that of Lot's wife. "Denn wer nicht vorwärts kommt der geht zürück; So war es immer so bleibt es." Unless the spirit of enquiry is developed deep and abiding intellectual interests are impossible. In its absence we become mere gatherers-in of knowledge with but a slightly higher degree of intelligence than that possessed by collectors, but lacking genuine interest in progress. The spirit of discovery is generally accompanied by a childlike freedom from bias. Without the inspiration that comes from prosecuting research, our gaze is directed down into the valleys and not upwards to the peaks whither our aspirations lead us. The failure of our universities to encourage more extensively than has yet been attempted enquiries in the field of knowledge is largely responsible for our diffuse and shallow interests. We are prone to estimate the mental qualities of a student by counting the number of subjects he has studied without attempting an analysis of his mental traits. Any institution which publicly assumes the right to be the bestower of a liberal education should be prepared to forfeit its claim to the title of university, as this should be a function of the school and not of the university. The essence of a liberal education is to be sought for in the quality of mind of the individual and not in the character of the information he possesses. The futility of any institution solemnly prom-

ising to be the dispenser of these special mental traits during the latter years of the educational curriculum is quite obvious to those who know that mental habits are, to a large extent, definitely and permanently formed much earlier than this period. If the qualities commonly designated as balance, interest and sympathy, the dominant characteristics of those who actually possess a liberal education have not budded in the school period, they can not be successfully grafted during the university years. The formation of mental habits belongs to the school and not to the university period. To-day the university unfortunately limits its sphere of usefulness in our intellectual life to frittering away energies and resources in attempting to reeducate those who have failed to develop intellectual interests during the school years. At the age of seventeen or eighteen, when the average student enters the university, his mental habits are already formed to such a degree that the catalogued promises made to him of the efficacy of liberalizing studies smacks more of the east wind of authority than of common sense. If those who defend the present conditions of affairs as a necessary form of compromise are correct, then we may well be pessimistic of our future intellectual development, inasmuch as the university is revealed to us as a nurse for the sick rather than as a counselor and aid to the strong. The dominance of that kind of mediocrity which imperils the life of democracy is very plainly indicated in the present organization of our universities that make ample provision for the day-nursery treatment of those who are devoid of intellectual interests and ambitions, and take little cognizance of the great numbers of students possessed of mental health, vigor and praiseworthy ambitions.

Many parents and teachers have the unfortunate habit of assuming a semi-apologetic attitude when referring to courses of studies, as if they were tasks to be undertaken merely in order to satisfy the conventional demands of society, while all manly virtues are commonly referred to as if they could only be exercised by training the biceps and were quite independent of brain development.

At school attention should be directed to the value of constant continuous effort, emphasizing the fact that a desire to work with one's brain is just as much a sign of health as the wish to excel in physical exercises. The importance of mental habits and the formation of thought processes should be emphasized not only as a means of attaining success in practical issues, but as the essential factors in the preservation of mental balance.

The silly conventional values commonly attached to an education should be replaced by substituting those intellectual interests in work that add so materially to the pleasure of living. The success of an education and the intelligent interest of an individual in his occupations may often be directly measured by estimating the degree of pleasure taken in "talking shop." The devitalizing influences of our

present system of educational ideals is seen in the urgent desire of many college graduates to lead a double sort of existence, one half of the day with, and the other without, their professional interests. The attitude of so many college graduates to their profession is of such a nature that "hobbies" and "outside interests" are essential for the restoration of the mental balance which has been destroyed by the daily occupation. This "double life" necessitating a daily shift in ideals and ideas may become a prolific source of nervous disorders, varying in degree from boredom, even at the mention of intellectual topics, to pronounced mental derangements. The failure of our present collegiate-university to show that the real pleasure of life depends upon the association and not upon the divorce of intellectual interests from the daily occupation of the individual is one of the most serious defects in a system that sets a man adrift in his profession without any intelligent interest in it. The American student is so thoroughly imbued with the idea that "to be educated" is a condition or state of mind induced by teachers that he seldom realizes any of the pleasures associated with learning; and so in later years the practise of his profession becomes for him merely a method of making a living instead of being at the same time a source of enjoyment.

By exhortation, backed up by a vigorous policing, the American collegiate university has endeavored to drive students to the choice of high ideals, which are emphasized merely in order to satisfy conventional requirements. This is one of the most serious defects in our entire educational system, as it frequently becomes necessary in after life for the individual at a critical period to readjust fundamental mental mechanisms in order to meet the real issues of life. On the other hand, the cultivation of the spirit of intelligent and candid scepticism has been sadly neglected in our American universities. Students are taught to think only in accordance with the "cast iron rules" given them as guides to thought and conduct, while the more important lessons of searching diligently for the truth, and of being continually on the guard lest the rising mists of authority completely blind their vision, are seldom emphasized. The ideals of the alma mater more often suggest submission to a corporal than to the admonitions of a parent. In many of our universities to-day the doubts of the weak are crushed out of existence, while the resistance of the strong to a system of passive intellectual oppression breeds a spirit of rebellion. High ideals can not be maintained in an atmosphere where the value of intellectual honesty is not appreciated, or where the advice is not infrequently given, "Do not express your doubts in public."

Pater's affirmation, "What we have to do is to be forever curiously testing new opinions and courting new impressions, never acquiescing in a facile orthodoxy of Compte, or of Hegel, or of our own," expresses a well-known law of physiology seldom referred to in our universities.

The spirit of the real university should reflect the characteristics of youth in its love of testing new opinions and courting new impressions. Without the presence of a large body of investigators an institution ceases to live or, if vitality is prolonged, it is merely of the vegetative type. The spirit of investigation leads men to conquer difficulties which would terrify them if they were driven into the breach solely by the voices of authority. The spirit of investigation is as important to the artist, the business man and the writer as it is to the scientist in his laboratory. The American university has not yet succeeded in injecting the energy proportional to its resources into our intellectual life, because it has not yet attempted to develop the driving power which alone can save us from the disastrous results of having so recklessly sacrificed the heritage of youth. The majority of the graduates who yearly go out from the doors of our higher institutions of learning without any definite intellectual interests have passed directly from the period of adolescence to that of old age.

The intellectual vigor of the average college graduate has been dwarfed by the conventional system of education, in which the spirit of dogmatism in teaching crowds out most of the natural impulses to learn. He is not given a moment in which to develop any ardor for the pursuit of knowledge. Little emphasis is given in the curriculum to the value of research, and this lack destroys initiative and smothers individuality by catering to the wishes of those educational promoters who are always eager to gain prestige by organizing personally conducted parties in search of liberal education and general culture. Another very serious defect in the curriculum of our universities is shown in the effort made to protract the period of training the acquisitive functions at a time when the initiating and productive capacity of the student should be developed to the highest degree possible. The most productive years of the average student in our universities are now wasted in copying models at a time when they should be encouraged "to block out their own ideas."

There is no civilized nation which should be as optimistic of its intellectual development as the United States. The fact that ideas and ideals have not been completely crushed out of existence by the perpetuation of school methods during the university years is the best testimony that the innate qualities of the American mind have extraordinary powers of growth even among most unfavorable environments. The relation of the alma mater to the majority of college students is that of the governess to pupils, deliberately sacrificing vigorous mental traits for drawing-room accomplishments. Our American higher institutions of learning pay far too much attention to the cultivation of mere forms of thought, and have neglected the study of the mechanism and laws of thought production.

The period of vigorous manhood is, as has already been indicated,

characterized by a keen interest in the advancement of learning. Those who do not comprehend or sympathize with the investigator are deficient in the mental traits which are preeminently characteristic of the normal individual during the prime of life, and express the highest aspirations of our race. The chief value of research to a university is to be found in the presence of a body of men who, in spite of their years, retain their interest and progressive ideas longer than those who have more sympathy with the methods of the pedagogue than with those who are desirous of learning. We may best maintain the traditions and the highest instinctive tendencies of our race by encouraging productive scholarship. In a brilliant passage, the author of the "Foundations of the Nineteenth Century" has shown that the spirit of discovery is the conscience of Teutonic learning. When our energies are restricted merely to familiarizing ourselves with the learning of the past, or in attempting to enter the domain of speculative thought in which the Greek intellect reigned supreme, we throw away our heritage and precipitate conflicts between inherited and acquired trends of thought that often end in intellectual apathy. In order to vitalize the knowledge of a dead past, we must inject into it the spirit of discovery which alone reflects the highest aspirations of our race. The lack of idealism and the spirit of indifference so often characteristic of the graduates of many of our universities is in a large measure the product of an educational system which, by ignoring objectivity in teaching and failing to cultivate the spirit of enquiry, has ignored the underlying trends of thought that, if properly directed, can bring us nearer to the ideals compatible with our social traits. To endeavor to satisfy the intellectual needs of our race by continually repressing the spirit of enquiry and by driving students to contemplative reflection upon the accumulated stores of knowledge, is equivalent to exchanging the driving force or spirit, that is born in us, for a suit of clothes. When the specific racial tendencies reflected in the spirit of discovery are not intelligently directed they find expression in utilitarian motives. By attempting, as does our educational system, to force American students to become passive recipients of knowledge, we are asking them to sell their heritage for a mess of pottage.

When once the essential distinction that exists between university and college is grasped, it is necessary to determine to what extent the present system of organization is favorable or antagonistic to the development of these two different types of institutions. An impartial examination of the facts such as is given in the excellent exposition of this entire subject by Cattell[1] shows how extremely difficult it will be for most of the older institutions which have assumed the name of university to prove their right to this title. As has already been pointed out, the present system of administration is adapted merely to

[1] *Science*, May 24 and 31, 1912.

the perpetuation of the college spirit and traditions. We have seen that the college without radical administrative reorganization can not "grow into" the university. The supposition that the natural development of the former will, according to the laws of growth, expand into the latter, is an assumption that has resulted in an unnecessary conflict of ideals; as those of the two institutions are not interchangeable. The unfortunate state of affairs is exemplified in more than one of our eastern universities, where we see the members of administrative boards, thoroughly imbued with the collegiate idea, attempting to carry out educational policies that do not conform with the ideals of members of the faculties, who have had greater opportunities for familiarizing themselves with university standards. When the attempt is made to effect a compromise, the efficiency of both institutions is seriously impaired and results in an interminable conflict of interests. The trustees who, as a rule, are unfamiliar with the nature of the university problems, often control its policy through the administration of the finances, even determining the election of presidents and the distribution of sums for educational purposes. As a result of this usurpation of powers the faculty is in danger of becoming merely a body of employees of the trustees, without any power to shape the educational policy of the institution.

The increased emoluments and the excessive prominence bestowed upon executive officers have had a disastrous effect in detracting from the appraised value of the work of scholar and investigator. The great eagerness with which administrative offices are sought for by members of the faculty show how extremely superficial are their intellectual interests. One can not imagine a Momsen, Pasteur or Darwin deliberately putting aside his special investigations in order to become an administrator.

The present system of organization has resulted in a temporary but, nevertheless, serious depreciation of the estimated value of scholarship; and has also given rise to an extreme spirit of Chauvinism, inimicable to the development of those mental qualities that underlie true culture. In executing a plan for the development of the university, boards of trustees defer largely to the wishes of the alumni of the institution. On account of the great and constant influence exerted by the large body of alumni, the older institutions in the east will find that it is increasingly difficult for them to identify their interests with those of the national life. Admirable as are a few of the influences which grow out of the "college spirit," there is a great deal that is objectionable and affords a suitable medium for the development of fixed ideas. The intense emotional reactions of the undergraduates and their more or less absurd sentimental devotion to the standards of a single institution give rise to conditions not specifically different from those that give fixity and undue valuation to many of the ideas characteristic of hys-

terical or paranoid states. When the public fully realizes that the development of the spirit of intelligent criticism should be one, if not the chief, end of education, it will become obvious that it is very difficult to attempt to bestow the elements of a liberal education in the collegiate atmosphere. One may quite as well expect the spirit of truth-telling to be acquired in an atmosphere permeated by falsehood as to believe the acquisition of mental balance is possible in surroundings in which feeling and sentiment dominate judgment and reason. The extreme partisanship cultivated in undergraduate life dominates many of the undertakings of the post-graduate, and its evil effects are particularly noticeable in the parochial character of administration of the professional schools (theology, law and medicine).

The entire intellectual life of our higher institutions of learning, and in time of the nation, would be revivified if the administration of these institutions were reorganized in order to meet the following conditions. (1) A clear understanding of the essential difference between college and university. (2) The determination by the administrative boards of these institutions to adopt a policy which shall be compatible with the ideals of either college or university, and not represent an unfortunate series of compromises ending in hopeless mediocrity. (3) A public confession of faith as to the value of intellectual ideals by repeated public affirmations, as expressed in words and deeds, to the effect that it is always more difficult to secure the services of great scholars than it is to obtain funds to be expended in bricks and mortar. (4) The establishment of democratic ideals of government in a form of organization which shall not be dominated by the autocracy of president and deans nor by an oligarchy of trustees; and finally (5) The substitution of national ideals of efficiency for the narrow local prejudices which so frequently restrict the life and sphere of usefulness of our universities.

Many of these reforms may readily be introduced by bringing the trustees and overseers into closer touch with the faculty, so that there may be a more direct exchange of views on important questions; and by the reorganization of the former bodies, so that the members may be made familiar with the aims and ideals of the university.

If our eastern universities persist in continuing their present parochial forms of administration, within the next decade we shall see a multiplication of independent foundations forming the nuclei or centers of university work. Half a century hence there will probably be a resurrection of the older and privately endowed colleges as state universities.

PROFESSOR EDMUND B. WILSON,

Professor of Zoology, Columbia University, President of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE

THE CLEVELAND CONVOCATION WEEK MEETING

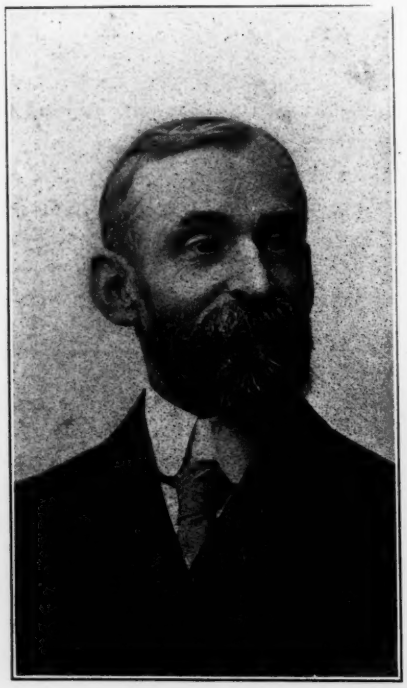
THERE was an excellent meeting of the American Association for the Advancement of Science and of the affiliated national scientific societies at Cleveland during the week of January first. The scope and magnitude of their work can be indicated by a statement of the number of papers on the program for the different sciences, namely:

Mathematics	49
Astronomy	35
Physics	52
Engineering	40
Geology	27
Zoology	84
Entomology	73
Botany	60
Phytopathology	49
Horticulture	53
Anthropology	27
Psychology	56
Biological chemistry and pharmacology	63
Anatomy	63
Physiology	67
Education	11
Economics and Sociology	13
Total	822

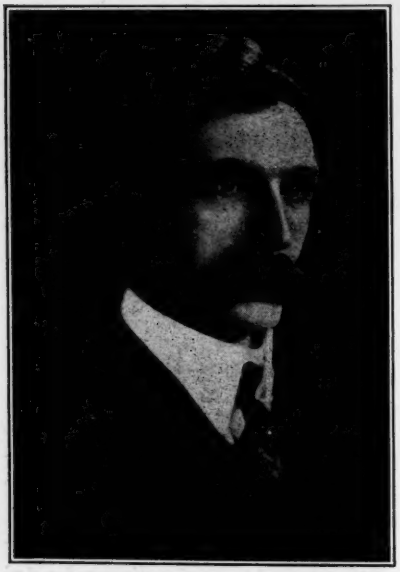
In no other country except Germany could there have been brought together such an extensive series of papers nearly every one of which was based on research work and contributed to knowledge. Such a program demonstrates an extraordinary extension of scientific work in the United States in the course of the past twenty years. It may appear that men of great distinction and contributions of noteworthy importance were not represented in proportion to the total number of those who read papers. But this is in part due to the circumstance that one does not see the trees on account of the forest. If the only advances made in science during the past year were represented by a dozen of the papers taken at random from the Cleveland program, each one of them would appear to be an important scientific contribution.

It is noticeable that the different sciences represented on the program contributed papers not far from equal in number, even though the sciences themselves may vary greatly in importance and in the number of its workers. Fifty to seventy papers are about as many as can be presented in a three-days' meeting, and most of the societies had about so many. Thus phytopathology was as largely represented as botany, entomology as zoology, physiology as physics. This seems to demonstrate the value of scientific organization, for if there had not been societies for the presentation of these papers, it may be that the work would never have been done.

There are several cases in which the program does not adequately represent the scientific work of the country. Thus the engineering societies do not meet with the association and the section of engineering is weakened. This year the chemists decided to meet separately like the engineers, partly because New Year's week, chosen as a time when college and university men can be present, is inconvenient for those engaged in industrial work. It seems desirable to increase rather than to decrease the contact of the pure and applied sciences, and it may be hoped that joint meetings may be arranged, perhaps at periods of three years. In that case the national societies devoted to economics, history and philology might also join in a great convocation



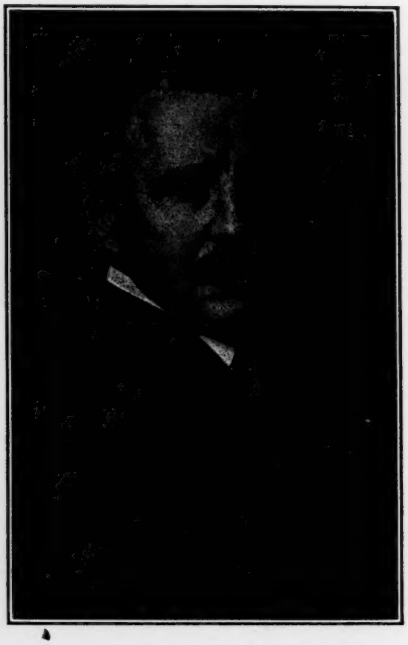
DR. E. B. VAN VLECK,
Professor of Mathematics at the University of Wisconsin, Vice-president for Mathematics and Astronomy.



DR. J. A. HOLMES,
Director of the Bureau of Mines, Vice-president for the Section of Geology.

week meeting, which would impress on those present and on the public the magnitude and weight of the work being accomplished for science and scholarship.

The American Association for the Advancement of Science and its affiliated societies have failed to accomplish as much as the British Association for the diffusion of science and in bringing together those engaged in scientific research and those who are or might become interested. Programs of gen-

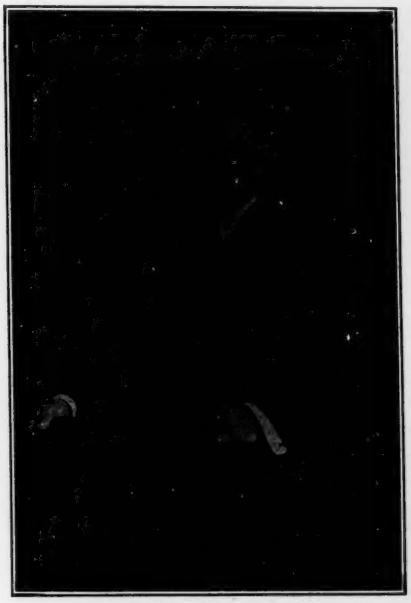


DR. WILLIAM A. LOCY,
Professor of Zoology at the Northwestern University, Vice-president for the Section of Zoology.

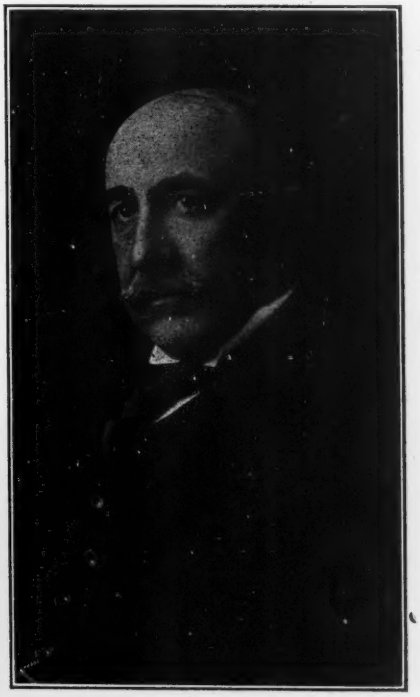
eral interest were arranged at Cleveland by nearly every section, but the attendance was practically confined to scientific men. Such meetings should be brought to general attention by full accounts in the local press and by reports throughout the country, but here almost complete failure must be confessed.

The council of the association took several steps intended to improve its

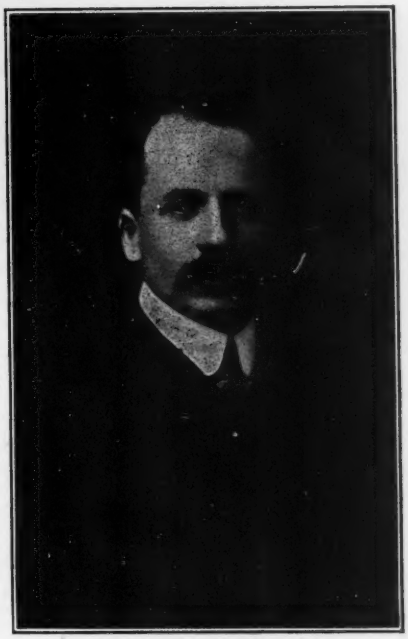
organization. The members on the Pacific coast, who number about 500, were authorized to make arrangements for a general meeting at the time of the Panama Pacific Exposition of 1915, and if they see fit to hold annual sectional scientific meetings. All institutions engaged in scientific research were requested to send delegates to the convocation-week meetings, paying their expenses when possible. In addition to the permanent secretary and the assistant secretary there was made provision for an associate secretary, who shall devote his entire time to the association and to the organization of scientific men.



DR. DUNCAN S. JOHNSON,
Professor of Botany at the Johns Hopkins University, Vice-president for the Section of Botany.

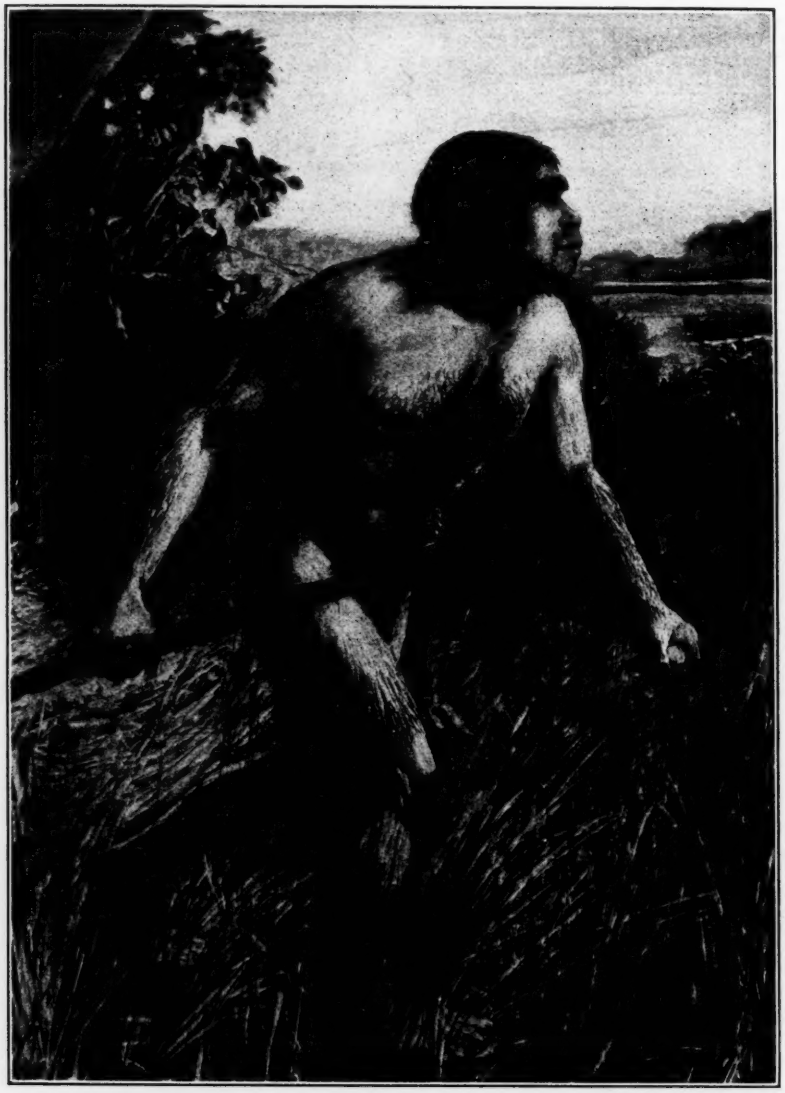


JOHN HAYS HAMMOND, LL.D.,
Vice-president of the Section of Social and Economic Science.



DR. J. J. R. MCLEOD,
Professor of Physiology at the Western Reserve University, Vice-president for the Section of Physiology.

The high scientific standing of the men responsible for the conduct of the work of the association is shown by the officers annually elected. We are able to reproduce here portraits of several of those who presided over the sections at the Cleveland meeting. The president of the association, Professor Edward C. Pickering, director of the Harvard College Observatory, is able to transfer this high office to Professor

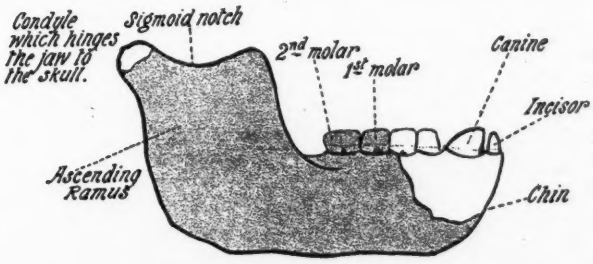


RECONSTRUCTION OF *Eoanthropus dawsoni*.

E. B. Wilson, professor of zoology at Columbia University. So long as the association is able to select presidents such as these, it bears witness to the fact that this country possesses men who unite scientific genius with personal distinction. The next convocation-week meeting will be at Atlanta; two years hence Philadelphia is proposed.

AN EXTINCT SPECIES OF MAN

AN anthropological discovery, rivalling in importance the discovery of *Pithecanthropus erectus* in Java by Dr. Du Bois twenty years ago, was communicated to the London Geological Society last month by Mr. Charles Dawson and Dr. A. S. Woodward, the keeper of the Geological Department of the British Museum. It appears



JAW OF *Eoanthropus dawsoni*.

that some four years ago Mr. Dawson noticed that a road had been recently mended by peculiar flints, and on tracing them to their source, he found that the laborers had dug out an object looking like a cocoa-nut, which they had thrown on a rubbish heap. This proved to be part of a human skull, and excavations of the undisturbed gravel where it was found discovered part of the jaw bone. A somewhat absurd cablegram was sent the newspapers in this country reporting the discovery of a fossil man who could reason before he could speak. But it is the case that the cranium is on the whole human in its characteristics, while the jaw tends to be simian.

A restoration of the jaw by Dr. W. P. Pycraft, of the British Museum, is here given, and a more fanciful reconstruction of the primitive man, drawn under his direction by Mr. Forestier for the *Illustrated London News*. The remains were found on a plateau 80 feet above the river-bed, to which extent denudation had taken place since the gravel was formed. In it were also found the remains of extinct mammals and many water-worn, iron-stained flint artifacts, to which the term eoliths has been applied. The gravel is early pleistocene, near enough to pliocene to make it almost certain that the immediate ancestors of the pleistocene man must have lived during that period.

The cranium is fragmentary, but typically human, with a capacity of over a thousand cubic centimeters, indicating a brain about four fifths that of the average European and twice as large as that of the highest apes. The bones are remarkably thick and the temporal muscles extend higher up on the skull than in any recent or fossil man. The jaw bears some resemblance to the Heidelberg jaw, but it is less massive, with a still more negative chin and other simian features. As restored it is much like that of the chimpanzee. Dr. Woodward regards the remains as belonging not only to a hitherto unknown species, but has erected for it a new genus to which the name *Eoanthropus dawsoni* has been given. Recent discoveries prove that primitive man at a period from one hundred thousand to a million years ago was widely spread over Europe and apparently as far as Java, and that different species and perhaps genera may have lived simultaneously in different regions.

THE SEALS OF THE PRIBILOF ISLANDS

PRESIDENT TAFT has sent a special message to the congress recommending the repeal of the law passed on February 15 of last year prohibiting the killing of seals on the Pribilof Islands for five years. His recommendation and that of the experts of the government should certainly be followed by the congress. A clear statement of the whole situation, drawn up by Dr. David Starr Jordan and Mr. G. A. Clark, has been recently given out by the Bureau of Fisheries of the Department of Commerce and Labor. The Pribilof Islands in Bering Sea came into the possession of the United States in 1867, and our

government has received about ten million dollars in royalties paid on seal skins. At the time of the transfer to the United States, the herd numbered about two and a half million animals, but has now been reduced to about one tenth of that number. The decline was due to pelagic sealing which took advantage of the migration journeys and distant feeding habits of the seals to kill them in the open sea. In 1894 about 60,000 animals from the Pribilof herd were killed in this way, mostly females with unborn young or with pups in the rookeries. It is said, further, that from a half to three quarters of the seals shot in pelagic sealing are never recovered.

Many efforts were made to do away with the evils of pelagic sealing, and finally in 1911 a treaty was drawn up according to which the United States and Russia, as owners of the principal fur seal herds, agreed to pay to Great Britain and Japan fifteen per cent. each of the product of their land-sealing operations, on condition that pelagic sealing be abolished by those nations for fifteen years. If no seals are killed on the Pribilof Islands, the treaty would be practically made of no effect, and one might expect pelagic sealing to be resumed. It is also true that those best informed on the subject hold that the killing of superfluous bulls is a real advantage to the herd. The seal is a polygamous animal, each bull having an average family of fifty cows. Fear of the adult males causes the young males to herd by themselves, and they may be driven away and handled like cattle. If there are too many bulls, there is continuous fighting, and the pups are killed. The conditions are somewhat similar to those in the raising of cattle, the experts wishing to use the methods commonly in vogue, whereas the suspension of the killing of superfluous males would lead to the condition in which calves are being raised in a field in which there are a hundred cows and a hundred bulls.

It is certainly to be hoped that the congress will accept the recommendation of President Taft and its own experts and not interfere with the proper interpretation of the treaty of 1911 and the best treatment of the seal herd of the Pribilof Islands.

SCIENTIFIC ITEMS

WE regret to record the death of Dr. Lewis Swift, formerly director of Mt. Lowe Observatory, known for his discoveries of comets and nebulæ; of Mr. Samuel Arthur Sanders, a British astronomer, and of Mr. William G. Tegetmeier, the English naturalist.

THE national scientific societies at the recent convocation-week meetings elected presidents, as follows: the American Physical Society, Professor B. O. Peirce, of Harvard University; the Geological Society of America, Professor Eugene A. Smith, professor emeritus of the University of Alabama and state geologist; the Society of American Bacteriologists, Professor C. E.-A. Winslow, of the College of the City of New York; the American Botanical Society, Professor D. H. Campbell, of Stanford University; the American Anthropological Association, Professor Roland B. Dixon, of Harvard University; the American Psychological Association, Professor C. H. Warren, of Princeton University; the Society of the Sigma Xi, Professor J. McKeen Cattell, of Columbia University; the American Society of Naturalists, Professor Ross G. Harrison, of Yale University; the American Economic Association, Professor David I. Kinley, of the University of Illinois; the American Historical Association, Professor William A. Dunning, of Columbia University.

IT has been proposed to municipal authorities of Paris that the memory of Henri Poincaré should be honored where he taught, and it is suggested that the portion of the Rue Vaugirard between the Boulevard St. Michel and the Odéon should be named after him.